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# Record of Decision
# Operable Unit 1 and Operable Unit 2
# Lower Fox River and Green Bay, Wisconsin




## Record of Decision
## Responsiveness Summary

**December 2002**

# Record of Decision
Operable Unit 1 and Operable Unit 2

Lower Fox River and Green Bay Site
Wisconsin

December 2002

**SUPERFUND RECORD OF DECISION (ROD)**
**for Operable Units I and 2**
**Wisconsin DNR and U.S. EPA**

**Lower Fox River**
**Brown, Outagamie, and Winnebago Counties, Wisconsin,**
**WID000195481**
**December 2002**

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| API/NCR - | Appleton Papers Inc./NCR Corp. |
| ARAR - | applicable or relevant and appropriate requirement |
| AR - | administrative record |
| AOC - | Administrative Order on Consent or Area of Concern |
| BTAG - | Biological Technical Assistance Group |
| BLERA - | Baseline Ecological Risk Assessment |
| BLRA - | Baseline Human Health and Ecological Risk Assessment |
| CERCLA - | Comprehensive Environmental Response, Compensation, and Liability Act |
| cfs - | cubic feet per second |
| CWA - | Clean Water Act |
| cy - | cubic yard |
| CIP - | Community Involvement Plan |
| CWAC - | Clean Water Action Council |
| COC - | Chemical of Concern |
| CT - | central tendency |
| CTE - | central tendency exposure |
| CSF - | Cancer Slope Factor |
| CDI - | Chronic Daily Intake |
| COPC - | Chemical of Potential Concern |
| CDF - | Confined Disposal Facility |
| CAD - | Confined Aquatic Disposal |
| DDT - | dichlorodiphenyltrichloroethane |
| DDD - | dichlorodiphenyldichloroethane |
| DDE - | Dieldrin |
| DO - | dissolved oxygen |
| EPA - | Environmental Protection Agency |
| ESD - | Explanation of Significant Difference |
| ERA - | Ecological Risk Assessment |
| FS - | Feasibility Study |
| FRFOOD - | Fox River Food Chain Model |
| FRC - | Fox River Coalition |
| FRG - | Fox River Group |
| FRDB - | Fox River Data Base |
| GBRAP - | Green Bay Remedial Action Plan |
| GBMBS - | Green Bay Mass Balance Study |
| GFT | Glass Furnace Technology |
| GLNPO - | Great Lakes National Program Office |
| HHRA - | Human Health Risk Assessment |
| HI - | Hazard Index |
| HQ - | Hazard Quotient |
| HTTD - | High-temperature Thermal Desorption |
| IRIS - | Integrated Risk Information System |
| IC - | institutional control |
| ISC - | in situ capping |
| IGP - | Intergovernmental Partnership |
| kg - | kilogram |
| LLBdM - | Little Lake Butte des Morts |
| LMMBS - | Lake Michigan Mass Balance Study |
| LOAEL - | Lowest Observed Adverse Effects Level |
| LOAEC - | Lowest Observed Adverse Effects Concentration |
| MNR - | Monitored Natural Recovery |
| mg/kg - | milligrams per kilogram |
| mg/kg/day - | milligrams per kilogram per day |
| NPL - | National Priorities List |
| NCP - | National Contingency Plan |
| NAS - | National Academies of Science |
| NOAA - | National Oceanographic and Atmospheric Administration |

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| NCR - | National Cash Register Corp. |
| NRDA - | Natural Resource Damages Assessment |
| ng/L - | nanograms per liter |
| NOAEL - | No Observed Adverse Effects Level |
| NOAEC - | No Observed Adverse Effects Concentration |
| NPDES - | National Pollutant Discharge Elimination System |
| NHPA - | National Historic Preservation Act |
| OU - | Operable Unit |
| OSWER - | Office of Solid Waste and Emergency Response |
| PCB - | Polychlorinated Biphenyl |
| ppm - | parts per million |
| PRP - | potentially responsible party |
| POTW - | publicly owned treatment works |
| ppb - | parts per billion |
| ppt - | parts per trillion |
| PAL - | preventive action limit |
| PEL - | probable exposure limit, |
| QA - | quality assurance |
| QA/QC - | quality assurance/quality control |
| RAL - | Remedial Action Level |
| RAP - | Remedial Action Plan |
| RI/FS - | Remedial Investigation/Feasibility Study |
| ROD - | Record of Decision |
| RI - | Remedial Investigation |
| RME - | Reasonable Maximum Exposure |
| RfD - | Reference Dose |
| RAO - | Remedial Action Objective |
| RCRA - | Resource Conservation and Recovery Act |
| SMU - | Sediment Management Unit |
| SERA - | Screening Ecological Risk Assessment |
| SMDP - | Scientific Management Decision Point |
| SLRA - | Screening Level Risk Assessment |
| SQT - | Sediment Quality Threshold |
| SWAC - | Surface Weighted Average Concentration |
| TAG - | Technical Assistance Grant |
| TEF - | toxic equivalency factor |
| TEL - | threshold exposure limit. |
| TRV - | toxicity reference values |
| TBC - | to be considered |
| TSCA - | Toxic Substances Control Act |
| TMDL - | Total Maximum Daily Load |
| USACE - | United States Army Corps of Engineers |
| USFWS - | United States Fish and Wildlife Service |
| USGS - | United States Geological Survey |
| UCL - | Upper Confidence Limit |
| WDNR - | Wisconsin Department of Natural Resources |
| WLA - | Waste Load Allocation |
| wLFRM - | whole Lower Fox River Model |
| WAC - | Wisconsin Administrative Code |
| WPDES - | Wisconsin Pollutant Discharge Elimination System |
| WDOT - | Wisconsin Department of Transportation |

# EXECUTIVE SUMMARY

## Record of Decision (ROD) for Operable Units I and 2 Wisconsin DNR & U.S. EPA

The Lower Fox River and Green Bay Site includes an approximately 39-mile stretch of the Lower Fox River as well as the bay of Green Bay. The river portion of the Site extends from the outlet of Lake Winnebago and continues downstream to the mouth of the River at Green Bay, Wisconsin. The Bay portion of the Site includes all of Green Bay from the city of Green Bay to the point where Green Bay enters Lake Michigan. This Record of Decision (ROD) addresses some of the human health and ecological risks posed to people and ecological receptors associated with polychlorinated biphenyls (PCBs) that have been released to the Site. Presently these PCBs reside primarily in the sediments in the River and in the Bay, and this ROD outlines a remedial plan to address a certain portion of PCB contaminated sediments.

The Site has been divided into certain discrete areas (Operable Units or OUs) for ease of management and administration. The River has been divided into Operable Units 1 through 4 and Green Bay constitutes Operable Unit 5. These Operable Units are:

Operable Unit 1 – Little Lake Butte des Morts
Operable Unit 2 – Appleton to Little Rapids
Operable Unit 3 – Little Rapids to De Pere
Operable Unit 4 – De Pere to Green Bay
Operable Unit 5 – Green Bay

This ROD selects a remedial action for Operable Units 1 and 2, and it is anticipated that a second ROD addressing Operable Units 3 through 5 will be issued in the future.

For many years along the Lower Fox River there have been and continue to be located an intense concentration of paper mills. Some of these mills operated de-inking facilities in connection with the recycling of paper. Others manufactured carbonless copy paper. In both the de-inking operations and the manufacturing of carbonless copy paper, these mills handled polychlorinated biphenyls (PCBs), which were used in the emulsion that coated carbonless copy paper. In the de-inking process and in the manufacturing process, PCBs were released from the mills to the River directly or after passing through local water treatment works. PCBs have a tendency to adhere to sediment and they have contaminated the River sediments. In addition, the PCBs and contaminated sediments were carried down river and released into Green Bay.

Presently, it is estimated that Operable Unit 1 contains approximately 4100 pounds of PCBs in 2,200,400 cubic yards of sediment. This ROD provides for the removal by hydraulic dredging 784,000 cubic yards of contaminated sediments from Operable Unit 1. The dredged material will be mechanically “dewatered” and taken to a landfill for permanent disposal. This ROD establishes an “action level” of 1 part per million (ppm) for this cleanup effort. In other words, any sediment found in Operable Unit 1 which has a concentration of PCBs of 1 ppm or greater will be targeted for removal. The goal of the remedial action in Operable Unit 1 is to reach a surface weighted average concentration (SWAC) of less than 0.25 ppm after dredging is completed. This means that the concentration of PCBs averaged over the Operable Unit will not exceed 0.25 ppm when the cleanup is complete. By removing the contaminated sediment, it is presently estimated that Operable Unit 1 will reach a surface weighted average concentration of 0.19 parts per million, well below the goal. By reducing the concentration of PCBs in

Operable Unit 1 to the SWAC level or below will dramatically reduce the human health and ecological risk.

Operable Unit 2, which is about 20 miles in length, contains approximately 240 pounds of PCBs in 339,200 cubic yards (cy) of sediment. A significant portion of the PCBs contained in this Operable Unit has already been removed through the sediment removal demonstration project at Deposit N. The result is that in Operable Unit 2 there remain no significant (i.e., greater than 10,000 cubic yards) contaminated sediment deposits with concentrations of PCBs above the action level. Moreover, it is contemplated that the farthest downstream deposit in Operable Unit 2 (Deposit DD) may be remediated in connection with the remedial action to be undertaken in Operable Unit 3 at a later time. Without active remediation, the SWAC for Operable Unit 2 is only 0.61ppm. Therefore for Operable Unit 2 the ROD selects a remedy of monitored natural recovery (MNR). This remedy does not involve sediment removal. Rather, it consists of a comprehensive monitoring program designed in part to monitor the levels of PCBs in various environmental compartments as the natural recovery processes work. Coupling this MNR with the substantial upstream dredging remedy in Operable Unit 1 should result in reduced human health or ecological risk in Operable Unit 2.

The estimated cost for the remedial action in Operable Unit 1 is $66.2 million and for Operable Unit 2 it is $9.9 million.

# Declaration for the Record of Decision (ROD) for Operable Units I and 2 Wisconsin DNR & U.S. EPA

**Lower Fox River**
**Brown, Outagamie, and Winnebago Counties, Wisconsin**
**WID000195481**
**December 2002**

## Part 1: Declaration for the Record of Decision

The Lower Fox River and Green Bay Site ("the Site" or "the Fox River Site") includes an approximately 39 mile section of the Lower Fox River, from Lake Winnebago down river to the mouth of the Fox River and all of Green Bay (approximately 2700 square miles in area). This stretch of the Fox River and Green Bay flows through or borders Brown, Door, Kewaunee, Marinette, Oconto, Outagamie, and Winnebago Counties, in Wisconsin, and, Delta and Menominee Counties in Michigan. The River portion of the Site has been divided into "Operable Units" (OUs) OU 1 through OU 4, and the Green Bay portion of the Site is designated OU 5 for purposes of Site management. The OUs were selected based, at least in part, on stretches of the River that have similar characteristics. They are OU 1 from the Lake Winnebago outlet to Appleton dam; OU 2 from the Appleton dam to Little Rapids dam; OU 3 from Little Rapids dam to the De Pere dam; OU 4 from the De Pere dam to the mouth of the River at Green Bay; and OU 5 Green Bay.

This Record of Decision ("this ROD") addresses the risks to people and ecological receptors associated with polychlorinated biphenyls (PCBs) in OUs 1 and 2; Little Lake Butte des Morts and Appleton to Little Rapids, respectively. PCBs are the primary risk driver, contained in sediment deposits located in the River and the Bay. The implementation of the remedy selected in this ROD will result in reduced risks to humans and ecological receptors living in and near the Site.

With the exception of continuing releases of PCBs from contaminated sediments, it is believed that the original PCB sources are now essentially controlled. PCBs in the River were from historical discharges, primarily related to carbonless copy paper manufacturing and recycling.

## STATEMENT OF BASIS AND PURPOSE

In June 1997, the United States Environmental Protection Agency (EPA) announced its intent to list the Fox River and portions of Green Bay on the National Priorities List (NPL), a list of the nation's hazardous waste sites eligible for investigation and cleanup under the federal Superfund program, and formally proposed listing of the Site to the NPL in a *Federal Register* publication on July 28, 1998. By agreement with EPA, the Wisconsin Department of Natural Resources (WDNR) is the "lead agency" with respect to the Site. This decision document was developed by WDNR for OUs 1 and 2 of the Fox River Site, pursuant to WDNR's authority under Ch. 292, Wisconsin Statutes. EPA has concurred and has adopted this ROD for the Fox River Site, as provided for in 40 CFR § 300.515(e).

This ROD was written in accordance with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), in a manner not inconsistent with the requirement of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part

300. This decision is based on information contained in the Administrative Record for this Site. This ROD is consistent with the findings of the National Academy of Sciences' (NAS) National Research Council report entitled *A Risk Management Strategy for PCB-Contaminated Sediments* and EPA policy.

## ASSESSMENT OF THE SITE

The response action selected in this ROD is necessary to protect the public health, welfare, or the environment from an imminent and substantial endangerment from actual or threatened releases of hazardous substances into the environment.

## DESCRIPTION OF THE SELECTED REMEDY

The objectives of the response actions for this Site are to protect public health, welfare and the environment and to comply with applicable federal and state laws. The selected remedy specifies response actions that will address PCB contaminated sediment in the Site's OUs 1 and 2. The WDNR and EPA (Agencies) believe the remedial actions outlined in this ROD, if properly implemented, will result in the cleanup of contaminated sediments in OUs 1 and 2 and will protect human health and the environment. Among the goals for the selected remedy are the removal of fish consumption advisories and the protection of the fish and wildlife that use the Fox River and Green Bay, and to reduce the transport of PCBs from the Fox River to Green Bay.

The major components of the selected remedy include:

- Removal of a total of approximately 784,000 cubic yards (cy) of contaminated sediment containing over 1715 kilograms (kg) or 3770 pounds of PCBs from OU 1 using environmental dredging techniques that minimize adverse environmental impacts. The selected remedy calls for de-watering and stabilizing the dredged sediment and disposing of it off site at existing licensed facilities and/or new facilities yet to be constructed and licensed in the Fox River Valley. In conducting the design of this remedy, WDNR and EPA may utilize vitrification of dredged contaminated sediment, as an alternative to off-site disposal at a licensed facility, if this is determined to be practicable and cost effective.
- The use of natural recovery processes and monitoring for OU 2, with the possible exception of deposit DD. A final decision on deposit DD will be made when the ROD for OU 3 is issued.
- Monitored Natural Recovery (MNR) of the residual PCB contamination remaining in dredged areas and undisturbed areas until the concentrations of PCBs in fish tissue are reduced to an acceptable level. Fish consumption advisories and fishing restrictions will remain in place until acceptable PCB levels are achieved.
- A long term monitoring program (water, sediment and tissue) throughout the OU 1 and 2 to determine the effectiveness of the remedy.

## STATUTORY DETERMINATIONS

The selected remedy meets the requirements for remedial actions set forth in Section 121 of CERCLA, 42 USC § 9621. It is protective of human health and the environment, complies with federal and state applicable or relevant and appropriate requirements, and is cost effective. The selected remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable. It does not completely satisfy the statutory preference for treatment as a principal element of the remedy, because PCB-contaminated sediment may not be treated prior to disposal.

With respect to the portions of the Fox River addressed in this Record of Decision, some PCB concentrations create a risk in the range of $10^{-3}$ or more, thus "qualifying" those sediments to be a principal threat waste. The preference for treatment applies to these particular sediments. However, it would be wholly impracticable to closely identify, isolate and treat these principal threat wastes differently than the other PCB sediments identified for removal and disposal. Typical dredging technology that may be employed may not be capable of distinguishing among such fine gradations of PCB concentrations. Nevertheless, at the conclusion of the OU 1 remedy the principal threat wastes will have been removed from OU 1 and deposited in a landfill. In so doing, the mobility of the principal threat wastes will have been greatly reduced.

Because the selected remedy will result in hazardous substances remaining on the Site above levels that allow unlimited use and unrestricted exposure, five-year reviews will be conducted.

## DATA CERTIFICATION CHECKLIST

The following information is in the *Decision Summary* section of this ROD. Additional information is in the Administrative Record file for this Site.

- Chemicals of concern and their respective concentrations - Sections 6 and 8
- Baseline risk presented by the chemicals of concern - Section 8
- Cleanup levels established for the chemical of concern and the basis for these levels - Section 13.3
- How source materials constituting principal threats are addressed - Section 12
- Surface water and land use assumptions used in the baseline risk assessments and ROD - Sections 7 and 8
- Potential land and ground water use that will be available at the Site as a result of the Selected Remedy - Section 7
- Estimated capital, operation and maintenance and total present-worth costs; and the time to implement each of the various remedial alternatives - Sections 11 and 13.2
- Key factors that led to selecting the remedy (i.e., best balance of trade-offs with respect to the balancing and modifying criteria) - Sections 11 and 14

12/18/02
Date

Bruce Baker, Deputy Administrator
Water Division
Wisconsin DNR

By signing this ROD, U.S. EPA Regions 5 concurs with the selected remedy.

12/20/02
Date

Wm. E. Muno
William E. Muno, Director
Superfund Division
U.S. EPA – Region 5

**SUPERFUND RECORD OF DECISION (ROD)**
**for Operable Units I and 2**
**Wisconsin DNR and U.S. EPA**

**Lower Fox River**
**Brown, Outagamie, and Winnebago Counties, Wisconsin,**
**CERCLIS ID: WID000195481**
**December, 2002**

## Part 2: Superfund Record of Decision

## 1. SITE NAME, LOCATION, AND BRIEF DESCRIPTION

### 1.1 Site Name and Location

The Lower Fox River and Green Bay Site is located in Northeast Wisconsin (in Brown, Door, Marinette, Oconto, Outagamie, Kewaunee, and Winnebago Counties), and the Eastern portion of Upper Peninsula of Michigan, (in Delta and Menominee Counties). The Lower Fox River flows northeast from Lake Winnebago for 39 miles where it discharges into Green Bay. Green Bay is approximately 119 miles long and is an average of 23 miles wide (Figure 1).

The Lower Fox River and Green Bay have been divided into 5 Operable Units (OU) by WDNR and EPA. For purposes of the RI/FS, the River was divided into four River reaches and Green Bay was divided into three major zones on the basis of physical features and information generated in previous investigations. Each of the River reaches has been deemed a separate Operable Unit (OU 1 through OU 4), while all of Green Bay has been designated a single Operable Unit (OU 5). An Operable Unit is a geographical area designated for the purpose of analyzing and implementing remedial actions. OUs are defined on the basis of similar physical and geographic properties and characteristics. The River reaches, Green Bay zones, and corresponding Operable Units are:

1. OU 1 – Little Lake Butte des Morts River reach
2. OU 2 – Appleton to Little Rapids River reach
3. OU 3 – Little Rapids to De Pere River reach
4. OU 4 – De Pere to Green Bay River reach
5. OU 5 – Green Bay

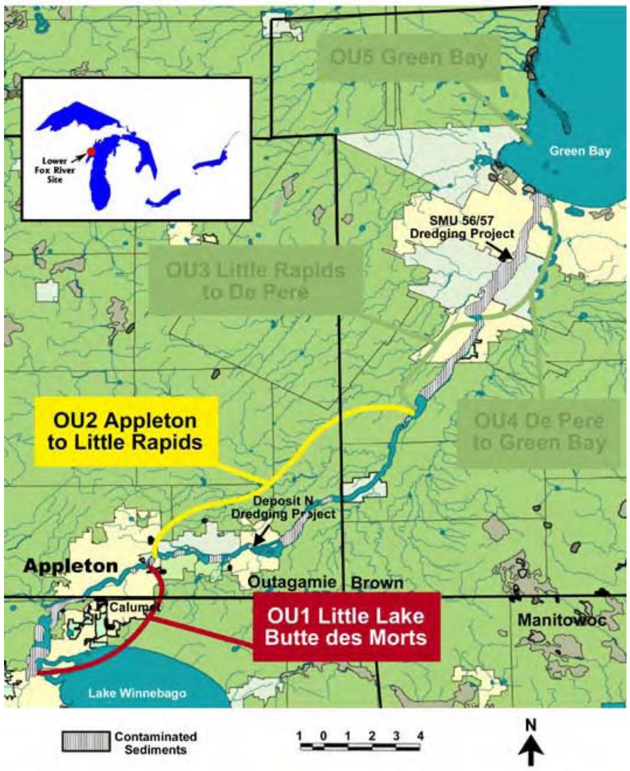
This ROD addresses Operable Units 1 and 2. For OU 1, active remediation (dredging, dewatering, stabilization or vitrification and on-site or off-site disposal) of in-place sediment has been selected. For OU 2, a monitoring program has been selected to evaluate the effectiveness of natural processes that are expected to reduce risk over time. Risk reduction will occur more quickly in OU 1 due to active remediation of that Operable Unit.

The remedial action selected herein is to remove and isolate, or otherwise ameliorate the threats to human health and the environment in OU 1 and OU 2 caused by the release of PCBs into the upper part of the Lower Fox River. While the release of PCBs to the environment occurred between 1954 and the late 1970s, the PCB contamination in the sediments continues to act as a source to the water, biota, and air.

## 1.2 Brief Description

The study area comprises two distinctly different water bodies, the Lower Fox River and Lake Michigan's Green Bay (Figure 1). The Lower Fox River flows northeast approximately 39 miles from Lake Winnebago to the River mouth at the southern end of Green Bay. Green Bay's watershed drains approximately 15,625 square miles. Two-thirds of the Green Bay basin is in Wisconsin; the remaining one-third is in Michigan's Upper Peninsula.

**Figure 1 Lower Fox River PCB Contaminated Sediment Deposits and Operable Units**




The Lower Fox River is the primary tributary to Green Bay, draining approximately 6,330 miles$^2$. The River's elevation drops approximately 168 ft between Lake Winnebago and Green Bay. Twelve dams and 17 locks accommodate this elevation change and allow navigation between Lake Winnebago and Green Bay. While the entire Lower Fox River still has a federally authorized navigation channel and is navigable by recreational boats, the Rapide Croche lock is permanently closed to restrict upstream migration of the sea lamprey.

The Lower Fox River is generally less than 1,000 ft wide over much of its length and is up to approximately 20 ft deep in some areas. Where the River widens significantly, the depth generally decreases to less than 10 ft, and, in the case of Little Lake Butte des Morts (LLBdM), water depths range between 2 and 5 ft except in the main channel. The main channel of the River ranges from approximately 6 to 20 ft in depth.

Since 1918, flow in the Lower Fox River has been monitored at the Rapide Croche Dam, midway between Lake Winnebago and the River mouth. Mean annual discharge is approximately 4,237 cubic feet per second (cfs). The recorded maximum daily discharge of 24,000 cfs occurred on April 18, 1952; the minimum daily discharge of 138 cfs occurred on August 2, 1936. Flow in the River between Appleton and the Little Rapids Dam averages 0.78 f/s.

OU 1 is identified primarily as Little Lake Butte des Morts and extends from Lake Winnebago to the Appleton dam for a distance of approximately 6 miles. This reach includes sediment deposits A though H and POG. OU 2 extends from the Appleton dam to Little Rapids dam for a distance of approximately 32 km (20mi). This reach includes sediment deposits I through DD.

## 1.3 Lead Agency

The Wisconsin Department of Natural Resources (WDNR) is the lead agency for this project. The United States Environmental Protection Agency (EPA), the support agency, has worked jointly with WDNR in the development of this ROD and concurs with the decision described herein.

# 2. SITE HISTORY AND ENFORCEMENT ACTIVITIES

## 2.1 Site History

The Fox River Valley is one of the largest urbanized regions in the state of Wisconsin, with a population of approximately 400,000. The Fox River Valley has a significant concentration of pulp and paper industries, with 20 mills located along or near the Lower Fox River. Other important regional industries include metal working, printing, food and beverages, textiles, leather goods, wood products, and chemicals. In addition to heavy industrial land uses, the region also supports a mixture of agricultural, residential, light industrial, and conservancy uses, as well as wetlands. For investigative purposes, the Site is defined as the 39 river miles of the Lower Fox River and Green Bay to a line that extends between Washington Island, Wisconsin, and the Garden Peninsula of Michigan.

Problems related to water quality have been noted and measured in the Lower Fox River and lower Green Bay almost since the area was settled. Water quality studies were initiated in the early 1900s and have been conducted almost annually since. Between the early 1930s and mid-1970s, the population of desirable fish and other aquatic organisms in the system was poor. Recorded fish kills and the increasing predominance of organisms able to tolerate highly polluted conditions were found throughout the Lower Fox River and lower Green Bay. Few people used the River or lower Green Bay for recreation because of the poor water quality and the lack of a sport fishery. During this same time period, dissolved oxygen levels were often very low (2 milligrams per liter [mg/L] or less). The poor water quality was attributed to many sources such as the effluent discharged from pulp and paper mills and municipal sewage treatment plants.

In large part because of the federal Clean Water Act (1972), over time improved waste treatment systems began operations. As part of this effort, WDNR developed and implemented a Waste Load Allocation system to regulate the discharge of oxygen-demanding pollutants from wastewater treatment plants. Fish and aquatic life in the Lower Fox River and Green Bay have responded dramatically to the improved water quality conditions. Fishery surveys conducted from 1973 to the present indicate a sharp increase in the sport fish population. Species sensitive to water quality, such as lake trout, which were absent since the late 1800s or early 1900s, have been found in the River since 1977. These improvements resulted in a large part from a substantial reduction in organic wastes discharged into the River.

With the return of the sport fishery, human use of the River and Green Bay has also returned. Recognizing concerns about potential health impacts of PCBs in the environment and their bioaccumulative properties, WDNR began routinely monitoring contamination in fish in the early

1970s. Significantly elevated levels of PCBs were detected in all species of fish and all OUs. Measured concentrations of PCBs in fish were (and remain) above levels that have been shown to be harmful to human health. As a result, fish consumption advisories for the Site were first issued in 1976 and 1977 by WDNR and the state of Michigan, respectively. Fish consumption advisories remain in effect today. WDNR has continued to collect data on contaminant concentrations in fish tissue since that time.

**PCB Use in the Lower Fox River Valley**

The principal source of Polychlorinated Biphenyls (PCBs) in the Lower Fox River and Green Bay is from the manufacture and recycling of carbonless copy paper. The former National Cash Register Company (NCR) is credited with inventing carbonless copy paper. The method used microcapsules of a waxy material to enclose a colorless dye dissolved in PCBs. This material was manufactured as an emulsion and could be coated onto the back of a sheet of paper. A second reactive coating was then applied to the front of a second sheet of paper. When the two sheets were joined, an impact on the front sheet would rupture the capsules and allow the dye to react with the coating on the second sheet, leaving an identical image.

PCB discharges to the Lower Fox River resulted from the production and recycling of carbonless copy paper made with PCB-containing coating emulsions. Manufacturing carbonless paper using the PCB containing emulsion began in the Fox River Valley in 1954 and continued until 1971. The production of carbonless copy paper increased during the 1950s and 1960s and by 1971, approximately 7.5 percent of all office forms were printed on carbonless copy paper. With increased production of carbonless copy paper, PCBs began to appear in many types of paper products made using recycled carbonless copy paper. As documented in an EPA report, nearly all paper products contained detectable levels of PCBs by the late 1960s. During this time period, other Fox River Valley paper mills also began recycling wastepaper laden with PCBs. Evidence of PCBs in paper products includes studies conducted by the Institute of Paper Chemistry to determine the rate at which PCBs migrated from paper container materials to the food products contained in them.

The production of carbonless copy paper was discontinued after 1971 because of increased concern about PCBs in the environment. During the period of use (1954 – 1971) an estimated 13.6 million kg (30 million lbs.) of emulsion were estimated to be used in the production of carbonless copy paper produced in the Fox River Valley. PCBs were released into the Lower Fox River in discharge water from several facilities. By analyzing purchase, manufacturing, and discharge records, conservative estimates have shown that approximately 313,600 kg (690,000 lbs.) of PCBs were released to the Fox River environment during this time. Ninety-eight percent of the total PCBs released into the Lower Fox River had been released by the end of 1971. Ceasing production of carbonless copy paper and the wastewater control measures put in place by the Clean Water Act were effective in eliminating point sources. Non-point sources, such as PCB contaminated groundwater plumes, are not known to exist from any of the potentially responsible parties' sites.

## 2.2 Actions to Date

To date seven companies have been identified and formally notified by the governmental agencies as potentially responsible parties (PRPs) with respect to the PCB contamination. These companies include Appleton Paper Company, NCR, P.H. Glatfelter Company, Georgia Pacific (formerly Fort James), WTM1 (formerly Wisconsin Tissue), Riverside Paper Co., and U.S. Paper Co. This group is commonly referred to as the Fox River Group (FRG).

EPA's proposed inclusion of the Lower Fox River and Green Bay Site on the National Priorities List (NPL) defines the Site as the Lower Fox River from the outlet of Lake Winnebago to a point in Green Bay 27 miles from the River mouth. That Site is officially called the Fox River NRDA PCB Releases Site in the proposed NPL listing. This Site, for the purpose of the RI/FS and Proposed Plan, includes the 39 miles of the Lower Fox River and all of Green Bay. The federal trustees conducting a Natural Resource Damage Assessment (NRDA) have defined the Site somewhat differently from the proposed listing to include all of Green Bay and nearby areas of Lake Michigan.

With the finding that PCBs released into the Lower Fox River were appearing at harmful levels to human health and the environment, several cooperative efforts were initiated to document residual PCBs in the sediments, and the fate, transport, and risks of PCBs within the Lower Fox River and Green Bay. In 1989/90, following recommendations made in the Green Bay Remedial Action Plan, EPA and WDNR began a comprehensive sampling program of sediment, water, and biota in the Lower Fox River and Green Bay for use in the *Green Bay Mass Balance Study* (GBMBS).

The GBMBS was a pilot project to test the feasibility of using a mass balance approach for assessing the sources and fates of toxic pollutants spreading throughout the food chain. The objectives of the GBMBS were to:

1. Inventory and map PCB mass and contaminated sediment volume;
2. Calculate PCB fluxes into and out of the Lower Fox River and Green Bay by evaluating Lake Winnebago, point sources, landfills, groundwater, atmospheric contributions, and sediment resuspension;
3. Increase understanding of the physical, chemical, and biological processes that affect PCB fluxes;
4. Develop, calibrate, and validate computer models for the River and Bay systems; and,
5. Conduct predictive simulations using computer models to assist in assessing specific management scenarios and selecting specific remedial actions.

The GBMBS confirmed that the primary source (more than 95 percent) of the PCBs moving within the Lower Fox River is the river sediment itself. The contribution of PCBs from wastewater discharges, landfills, groundwater, and the atmosphere is insignificant in comparison to the PCBs originating from the sediment. Furthermore, the GBMBS showed that PCBs released from the sediments were directly linked to the levels of PCBs measured throughout the biological food chain, including fish, birds, and mammals that depend on the River for food.

Inventory and mapping activities showed that PCBs are distributed throughout the entire Lower Fox River. Thirty-five discrete sediment deposits were identified between Lake Winnebago and the De Pere Dam. One relatively large, continuous sediment deposit exists downstream of the De Pere Dam. Water column sampling indicated that the water entering the Lower Fox River from Lake Winnebago contains relatively low PCB concentrations. However, upon exposure to the contaminated river sediment in Little Lake Butte des Morts, water in the River exceeds state water quality standards. During the GBMBS, the lowest water column concentration (5 nanograms per liter [ng/L]) of PCBs measured in any River sample still exceeded the state water quality standard by a factor of more than 1,500. As expected, water column concentrations also increased as River flow increased and PCBs attached to River sediment were resuspended into the water column. These higher flows resulted in PCB concentrations that exceeded standards by a factor of almost 40,000. The GBMBS also documented that more than 60 percent of PCB transport occurs during the relatively short time when River flows are above normal. Movement of PCBs in the water column extends throughout Green Bay, with some PCBs from the Lower Fox River ultimately entering Lake

Michigan proper. The GBMBS also documented that a considerable amount of PCB is lost to the atmosphere from the surface of the water in the River and Bay.

EPA's Great Lakes National Program Office (GLNPO) initiated a similar mass balance study for all of Lake Michigan, the *Lake Michigan Mass Balance Study* (LMMBS). To accomplish the objectives of this study, which were similar to those of the GBMBS but on a larger scale, pollutant loading (including PCBs) from 11 major tributaries flowing into Lake Michigan was measured. The Lake Michigan Tributary Monitoring Program confirmed the magnitude and significance of the Lower Fox River contribution to pollutant loading in Lake Michigan. It is estimated that each day, up to 70 percent of the PCBs entering Lake Michigan via its tributaries are from the Lower Fox River.

In 1993, a group of paper mills approached WDNR to establish a cooperative process for resolving the contaminated sediment issue. The outcome was formation of the Fox River Coalition, a private-public partnership of area businesses, state and local officials, environmentalists, and others committed to improving the quality of the Lower Fox River. The Coalition focused on the technical, financial, and administrative issues that would need to be resolved to achieve a whole River cleanup.

The Coalition's first project was an RI/FS of several sediment deposits upstream of the De Pere Dam. The sediment deposits targeted for the Coalition's RI/FS were selected after all the deposits had been prioritized based on their threat and contribution to the contaminant problems. Previous studies on the River had focused only on the nature and extent of contamination. The Coalition's RI/FS first confirmed the nature and extent of the contamination within each deposit, then evaluated remedial technologies for cleaning up two of the deposits.

The Coalition also undertook a project to more thoroughly inventory and map sediment contamination in the River downstream of the De Pere Dam, collecting sediment cores from 113 locations. The sampling was completed in 1995 with technical and funding assistance from both WDNR and EPA. The resulting data led to a revised estimate of PCB mass and the volume of contaminated sediment in this River reach. The expanded database also made it possible to prioritize areas of sediment contamination, much as had previously been done for areas upstream of the De Pere Dam.

Following completion of the Coalition's RI/FS for the upstream sites, the Coalition selected Deposit N as an appropriate site for a pilot project to evaluate remedial design issues. The primary objectives were to determine requirements for implementing a cleanup project and to generate site-specific information about cleanup costs. Although the Coalition initiated the effort, WDNR, with funding from EPA, was responsible for implementing the Deposit N pilot project.

In 1994, the U.S. Department of the Interior acting through the U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce, the Menominee Indian Tribe of Wisconsin, and the Oneida Tribe of Indians of Wisconsin initiated a Natural Resources Damage Assessment (NRDA) for the Site. The State, federal and Tribal Trustees are working together to determine what is necessary to address natural resource injuries caused to-date by releases of PCBs. This is a separate, but related process to the remediation consideration discussed herein.

In January 1997, the WDNR and the FRG signed an agreement dedicating $10 million to fund demonstration projects on the River and other work to evaluate various methods of restoration. This collaborative effort, however, was not completely successful and did not resolve technical issues as was initially hoped. At about this same time, USFWS issued a formal Notice of Intent to sue the paper companies. In June 1997, the U.S. EPA announced its intent to list the Lower

Fox River and portions of Green Bay on the NPL, a list of the nation's hazardous waste sites eligible for investigation and cleanup under the federal Superfund program. The state indicated its opposition to listing the River as a Superfund site. Federal, state, and tribal officials subsequently signed an agreement on July 11, 1997 to share their resources in developing a comprehensive cleanup and restoration plan for the Lower Fox River and Green Bay. EPA formally proposed listing of the Site to the National Priorities List in the *Federal Register* on July 28, 1998.

In October 1997, the FRG submitted an offer to conduct an RI/FS on the Lower Fox River. An RI/FS is the first step in the federal process initiated by EPA to assess current health risks and evaluate potential remediation methods. Following unsuccessful attempts to negotiate this work activity with the FRG, EPA delegated the lead role for the Site to WDNR and helped craft a scope of work and cooperative agreement with WDNR for completing the RI/FS. WDNR, EPA, USFWS, NOAA, and the Menominee and Oneida Tribes worked in close cooperation to guide, review and issue the RI/FS. Two draft documents were released for public comment (1999, 2001). Comments received from the PRPs, the public, and independent peer review committees were incorporated into the Final RI/FS.

**Deposit N**

In 1998 and 1999, the WDNR and EPA-GLNPO sponsored a project to remove PCB-contaminated sediment from Deposit N in the Lower Fox River. This project was successful at meeting its primary objective by demonstrating that dredging of PCB-contaminated sediment can be performed in an environmentally safe and cost-effective manner. Other benefits of the project included the opportunity for public outreach and education on the subject of environmental dredging, as well as the actual removal of PCBs from the River system. Deposit N, located near Little Chute and Kimberly, Wisconsin, covered approximately 3 acres and contained about 11,000 cubic yards (cy) of sediment. PCB concentrations were as high as 186 milligrams per kilogram (mg/kg). Of the 11,000 cy in Deposit N, about 65 percent of the volume was targeted for removal.

Approximately 8,200 cy of sediment were removed, generating 6,500 tons of dewatered sediment that contained 112 total pounds of PCBs. The total included about 1,000 cy of sediment from Deposit O, another contaminated sediment deposit adjacent to Deposit N. Monitoring data showed that the River was protected during the dredging and that wastewater discharged back to the River complied with all permit conditions. The project met the design specifications for the removal, such as the volume of sediment removed, sediment tonnage, and allowed thickness of residual sediment. It should be noted that the project's goals were to test and meet the design specifications and focus on PCB mass removal, not to achieve a concentration-based cleanup, i.e., removal of all PCB-contaminated sediment above a certain cleanup level. A cost analysis of this project indicated that a significant portion of the funds was expended in pioneering efforts associated with the first PCB cleanup project on the Lower Fox River, for the winter construction necessary to meet an accelerated schedule, and for late season work in 1998.

**Fox River Group Demonstration Project**

As part of the January 1997 agreement between the FRG and the State of Wisconsin, the FRG agreed to make available a total of $10 million for a number of projects. One of these was a sediment remediation project for which the objective was to design, implement, and monitor a project downstream of the De Pere Dam. The project was intended to yield important information about large-scale sediment restoration projects in the Lower Fox River. The project, as described in the agreement, had a pre-defined financial limit of $8 million. The FRG and

WDNR agreed on Sediment Management Units 56 and 57 (SMU 56/57) as the project site. Contractors and consultants, under contract to the FRG, designed and implemented the project. Dredging at SMU 56/57 began on August 30, 1999. Dewatered sediment was trucked to a landfill owned and operated by Fort James Corporation (now Georgia Pacific). Because of cold weather and ice, dredging ceased on December 15, 1999, after approximately 31,350 cy of contaminated sediment containing more than 1,400 pounds of PCBs were removed from the River.

At the time this project was halted for the first year, SMU 56/57 had not met the project's dredging objective of removal of 80,000 cy of material. This resulted in unacceptably high concentrations of PCBs in surface sediment in portions of the dredged area. Despite this, the project provided instructive experience concerning hydraulic dredging. Building on the successes of this project, Fort James (now Georgia Pacific) worked cooperatively with WDNR and EPA in the spring of 2000 to complete the SMU 56/57 project. (See description of this enforcement agreement in Section 2.3, below). The sediment volume targeted for removal in 2000 was 50,000 cy. The additional volume of sediment removed from SMU 56/57 in 2000 was 50,316 cy, which was transported to the same Fort James landfill following dewatering. Approximately 670 pounds of PCBs were removed from SMU 56/57 during the 2000 project phase. Overall, the 1999 and 2000 efforts at SMU 56/57 resulted in the removal of approximately 2,070 pounds of PCBs from the River. The 2000 project phase met all goals set forth in the Administrative Order By Consent, and also met or exceeded the project's operational goals for removal rates, dredge slurry solids, filter cake solids, and production rates that were set forth for the original 1999 FRG project.

In February 1999, WDNR released a draft RI/FS for public review and comment. The draft RI/FS was released to solicit public comment early in the planning process, to better evaluate public acceptance, and to assist WDNR and U.S. EPA in selecting a cleanup alternative having the greatest public acceptance. Comments were received from other governmental agencies, the public, environmental groups, and private sector corporations. These comments were used to revise and refine the scope of work that led to the RI/FS and Proposed Remedial Action Plan (PRAP) released for public comment in October 2001.

### 2.3 Enforcement Activities

The work described above on SMU 56/57 was conducted from July to November 2000, under an Administrative Order By Consent (Docket No. V-W-00-C-596), that was entered into by Fort James, EPA, and the State of Wisconsin. Under its terms, Fort James funded and managed the project in 2000 with oversight from both WDNR and EPA.

An interim Consent Decree settlement was reached with Appleton Papers/NCR (API/NCR), with the Court entering the Decree on December 10, 2001. Under this agreement, API/NCR agrees to provide $10 million a year for both remediation and restoration work (under the NRD process), with projects determined by the Intergovernmental Partnership. In return, the Intergovernmental Partnership agree to not order API/NCR to do remediation or restoration work on the River for the 4-year life of the agreement.

## 3. COMMUNITY PARTICIPATION

### 3.1 Public Participation

The community/public participation activities to support selection of the remedy were conducted in accordance with CERCLA § 117 and the NCP § 300.430(f)(3).

More than 100 people were interviewed in late 1998 and early 1999 to develop the Site's community involvement plan (CIP). Residents, tribal members, elected officials, business organizations, local health staff, and environmental groups from the affected communities discussed their concerns and those discussions are included in the CIP. In addition, an extensive profile of each municipality and reservation, as well as history of the River, was completed for the CIP. The CIP was placed in the information repositories for the Site in 2001.

The information repositories are located at the Appleton Public Library; Oshkosh Public Library; Brown County Library in Green Bay; Door County Library in Sturgeon Bay; and Oneida Community Library.  Five additional locations, at the Kaukauna, Little Chute, Neenah, De Pere and Wrightstown Public Libraries, still maintain a fact sheet file, although they are no longer information repositories.

EPA awarded a $50,000 Technical Assistance Grant to the Clean Water Action Council (CWAC) in 1999 and another $50,000 grant was provided in 2001. The council has used its TAG to inform the community about the Lower Fox River investigations. To fulfill its obligations, CWAC developed a web site, printed flyers and bumper stickers, paid for newspaper ads and paid technical advisors to review EPA and WDNR-generated documents.

WDNR and EPA held numerous public meetings and availability sessions beginning in summer 1997 to explain how and why the Site was proposed for the Superfund NPL. In February 1999, a draft RI/FS (which did not identify a specific selected remedy) was released with a 45-day public comment period, which was extended an additional 60 days. Prior to and after the release of the draft RI/FS, WDNR and EPA provided for extensive community and public participation, and kept residents, local government officials, environmental organizations and other interest groups apprised of the steps of the process. Well-attended public meetings, small group discussions, meetings and presentations for local officials, and informal open houses continued through 2001.

The public meetings and proposed plan availability were announced to the public at a press conference on October 5, 2001, and received extensive coverage through TV, radio and newspapers news stories. The draft RI/FS and proposed plan were formally presented at public meetings held on October 29, 2001 in Appleton and October 30, 2001 in Green Bay. Additionally, WDNR and EPA mailed meeting reminders and proposed plan summaries to the 10,000 name Fox River mailing list. Press releases pertaining to the proposed plan, comment period, and public meetings were sent to newspapers and TV and radio stations throughout the Fox Valley. Display ads announcing the proposed plan, comment period and public meetings were also placed in Green Bay and Appleton newspapers. The presentations and question and answer sessions at the public meetings, and all public comments taken at the meetings, were recorded and transcribed. The written transcripts of the public meetings are available in the information repositories, the administrative record and on the WDNR Lower Fox River web page.

More than 20 public meetings and availability sessions have been held regarding the project. Cleanup and restoration activities, the status of pilot projects, fish consumption advisories, and the February 1999 draft RI/FS released by WDNR have been among the topics on which these meetings focused.  Additionally, over 15 small group and one-on-one interview sessions have been held.  Project staff have also made more than 60 presentations to interested organizations and groups. In addition, WDNR, EPA and their intergovernmental partners publish a bimonthly newsletter, the *Fox River Current*, which is mailed to over 10,000 addresses. To date, 23 issues of the *Fox River Current* have been published.

Copies of the various supporting reports and the proposed plan were made available to the public during a public comment period that began on October 5, 2001 and concluded on January 22, 2002. Approximately 4,800 written comments were received via letter, fax and e-mail. A copy of the Responsiveness Summary for these comments is attached to this ROD. Originally, the comment period was for 60 days, ending on December 7, 2001. The announcement of the extension until January 22 was published through newspaper advertisements and news releases on October 25, 2001. Newspaper advertisements were placed in the Green Bay Press Gazette and the Appleton Post Crescent announcing the availability of the plan and its supporting documents, and a brief summary of the plan in the information repositories. The proposed plan, the RI/FS and other supporting documents containing information upon which the proposed alternative was based were also made available on the Internet at www.dnr.state.us/org/water/wm/lowerfox/index.html and at the EPA Region 5 web site. All documents were also available as part of the Administrative Record housed at WDNR offices in Madison, Wisconsin and Green Bay, Wisconsin and at the EPA Region 5 office in Chicago, Illinois.

## 4. SCOPE AND ROLE OF RESPONSE ACTION

As with many Superfund sites, the problems at the Lower Fox River and Green Bay Site are complex. As a result, WDNR and EPA organized the Site into five OUs described in Section 1.1, above.

The Proposed Plan, issued October 2001, recommended a cleanup plan for all five Operable Units at the Site. However, at this time, WDNR and EPA are issuing a ROD for the Fox River OUs 1 and 2 only. WDNR and EPA expect to issue a ROD for OUs 3, 4 and 5 at a later date.

The reasons for issuing a ROD at this time for only OUs 1 and 2, and not for OUs 3, 4 and 5, are as follows:

- OU 1 and 2 represent a smaller portion of the area within the Fox River where remediation is necessary. These two Operable Units represent approximately 6.5 percent of the PCB mass and 18 percent of the sediment volume in the Lower Fox River. Consequently, these two Operable Units represent a more manageable project than conducting all of the remediation at one time.
- Provide a phased approach to the remedial work. Work on upstream areas, OUs 1-2 can start before the downstream areas, OUs 3, 4, and 5. This is consistent with the EPA policy Memorandum by Marianne Horinko, "OSWER Directive 8258.6-08, Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites," dated February 12, 2002. Principles described in this memorandum include, "Control Sources Early," and "Use an Iterative Approach in a Risk Based Framework." Additionally, the NCP states at 300 CFR Section 430(a)(1)(ii):

  > "*Program Management Principles.* EPA generally should consider the following general principles of program management during the remedial process:
  >
  > Sites should generally be remediated in Operable Units when....phased analysis and response is necessary or appropriate given the size or complexity of the site...."

- Planning for OUs 3, 4, and 5 may benefit from knowledge gained on the OUs 1 and 2 project.

The primary objective of this response action is to address the risks to human health and the environment due to PCBs in the in-place sediments of OUs 1 and 2 in the Lower Fox River. PCB concentrations remain elevated in Fox River sediments, in the water column and in the fish. Removal of the PCB-contaminated sediments will result in reduced PCB concentrations in fish tissue, thereby accelerating the reduction in future human health and ecological risks. In addition, by addressing the sediments, the remediation will control a source of PCBs to the water column, which contributes to fish tissue concentrations and transports PCBs into downstream reaches of the River, Green Bay, and eventually to Lake Michigan.

## 5. PEER REVIEW

To ensure the credibility of the scientific work conducted during the Remedial Investigation/Feasibility Study (RI/FS), EPA conducted both forms of peer involvement: peer input and peer review. Peer input was conducted through internal Agency reviews, and reviews by other agencies and Tribes. Peer review was also conducted, in accordance with EPA guidance outlined in the Peer Review Handbook (dated December 1998, updated December 2000). The peer review was conducted by independent experts who were unaffiliated with EPA, WDNR, the FRG or other Site stakeholders, and was undertaken on some of the major scientific aspects that form the basis for this decision.

Two separate EPA-sponsored peer review panels were convened. The review process consisted of each panel conducting an independent review by three panel members, with technical and administrative support by an EPA-contractor. The EPA contractor was responsible for convening the panels, consistent with the “charge” given by EPA for the panel review. This peer review was undertaken without influence by EPA, WDNR, the FRG or other interested parties. This was to provide an independent analysis and comment on key documents and issues related to development of a proposed remedy. Specifically, the panels were asked to evaluate:

- Adequacy of data considered in the 1999 Draft Lower Fox River Remedial Investigation, relative to quality and quantity (RI Panel), and
- Natural recovery and environmental transformation, i.e., biological breakdown of PCBs (FS Panel). Natural recovery was defined by the panel as naturally occurring physical, chemical, or biological processes that reduce the risks associated with contaminants in sediments over time.

Each peer review panel was asked to address specific questions (i.e., the “charge”) regarding the report being reviewed, including key controversial issues identified by EPA. The RI and FS panels issued reports October 7, 1999, and September 28, 1999, respectively.

The following summarizes the major findings of each of the panels:

- Data are adequate to determine the distribution of contaminants (i.e., it can be decided where cleanups should take place), if all data sources are considered (i.e., the RI does not provide a complete record).
- Data from all available sources are adequate to support identification and selection of a remedy for those technologies (e.g., dredging and capping) that have been used on a large scale at other, similar sites. Data are insufficient for developing in situ bio-technologies that may be applicable to the Site.
- Substantial improvements or additions to the existing data set are not indicated.

- The Draft FS should more fully evaluate natural recovery of sediments as a remedial alternative in comparison with other remedial options.
- The technical basis of the natural recovery analysis needs to be described in more detail to permit a review of the methodology used and to assess confidence in natural recovery predictions.

In the 2001 draft RI and FS and the Proposed Plan, WDNR and EPA considered the recommendations by the peer review panels, and on that basis made modifications to draft documents upon which the proposed plan was based.

In addition to EPA-sponsored peer reviews, the FRG sponsored peer reviews that were technically consistent with EPA peer review policy, although they may not have conformed to all aspects of the peer review process and documentation. These reviews consisted of the following analysis for the Fox River:

- Fate and transport and bio-uptake modeling evaluations by WDNR and the FRG;
- Human Health Risk Assessments by WDNR and the FRG
- Ecological Risk Assessments by WDNR and the FRG.

Recommendations by both EPA-sponsored peer reviews as well as those by the FRG were considered and incorporated into the 2001draft RI/FS, which was a significant part of the basis for the Proposed Plan.

# 6. SITE CHARACTERISTICS

## 6.1 Conceptual Site Model

The conceptual site model for the Fox River PCBs Site describes the source to receptor succession in simple terms and identifies the major contamination sources, contaminant release mechanisms, secondary sources, pathways and receptors of concern (see Figures 2 and 3). Figures 2 and 3 show both human and ecological site models. The design of field investigations and human and ecological risk assessments reflect the basic components of the conceptual site model.

In the conceptual site model, historical PCB releases were from paper manufacturing and recycling facilities that discharged into the Fox River. Although current releases are insignificant, historical releases were from discharge of wastewater containing PCBs. Contaminated sediment “hotspots” contribute to the overall PCB load in the Fox River and Green Bay.

Once introduced into the River, the PCBs adhere to sediments, with some fraction being carried in the water column. Physical, chemical and biological release mechanisms allow PCBs in the sediment to become available for redistribution and a source of PCB contamination to the water column. The sediments will continue to release contamination to the water column and biota, through aquatic and benthic food chains, as well as other not easily modeled processes such as boat scour, ice rafting, and bioturbation, unless they are managed or remediated in some manner. In addition, scour from water flowing over sediments during high flow events will continue to redistribute sediments and re-expose contaminants.

Because the River is a dynamic system with varying energy regimes, generally PCB-laden sediments are not sequestered or stable. Some PCB-contaminated sediment is buried by deposition of cleaner sediments at times, but in other places and at other times contaminants are redistributed. This redistribution may be local or more regional depending on the energy of flow events and/or physical type or size of the sediment particles. The redistributed sediments release contamination to the water column and high flow events (e.g., floods) further increase the bioavailability of contaminants to organisms in the water column. Although scour during high flow events is an important release mechanism PCBs in the surface water are also routinely observed during periods of lower flows (see Section 6.2.3, "Water Column," below). The conceptual site model shows that the fish ingestion pathway is a completed exposure route for the Site. Receptors include humans (e.g., anglers and their families), piscivorous (i.e., fish eating) fish, piscivorous birds (including threatened and endangered species) and mammals. Additional information on the human and ecological receptor populations is provided in the risk section (Section 8) of this document.

**Figure 2 Human Health Site Conceptual Model**

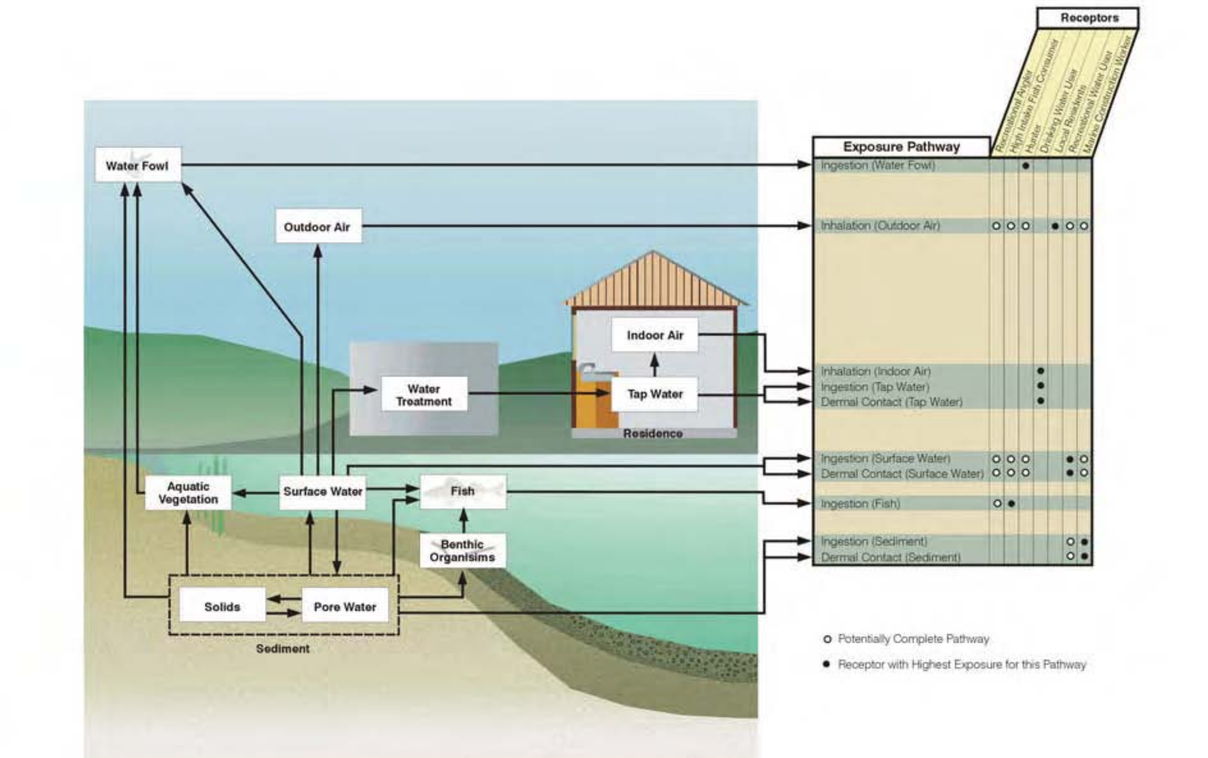
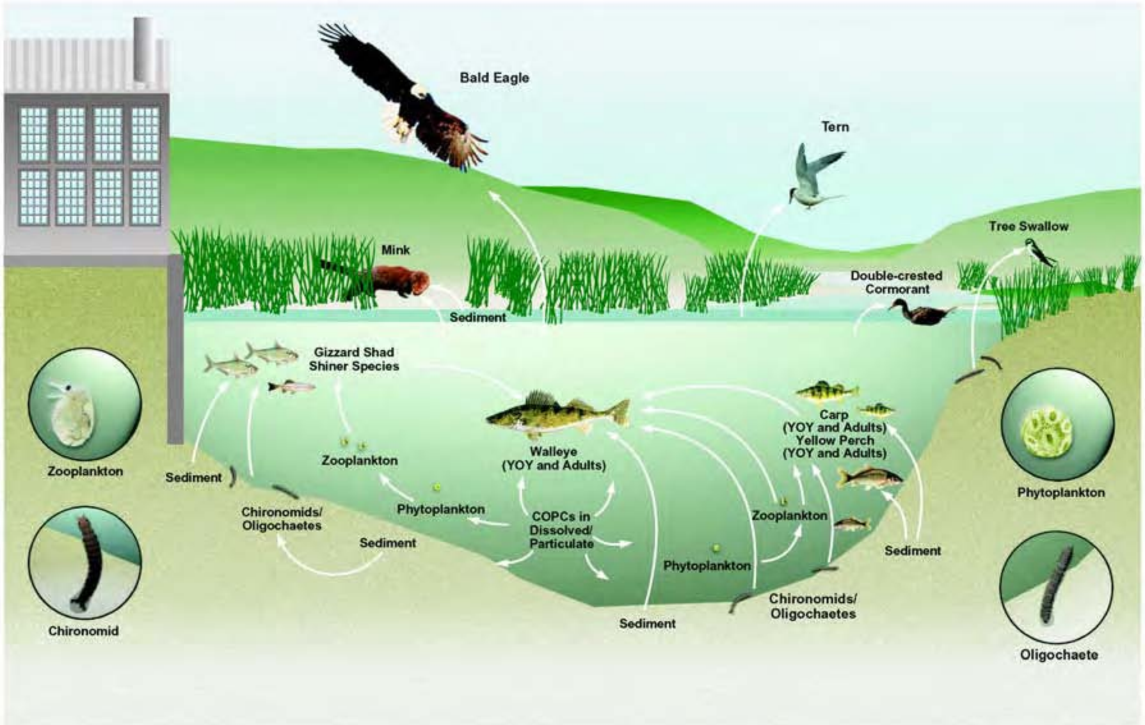


**Figure 3 Ecological Site Conceptual Model**




## 6.2 Results of the Remedial Investigation

### 6.2.1 Site Overview

The Lower Fox River is a large freshwater river that has been contaminated with PCBs for nearly 50 years. The contaminated portions of the Lower Fox River include variations in hydrology and river bed geology, which create complex environmental setting with varying levels of PCB contamination.

### 6.2.2 Summary of Sampling Results

WDNR's RI/FS evaluated data from numerous prior investigations conducted since 1971. These data have been incorporated into a single Fox River Database, available at WDNR's Lower Fox River Web page. The data received as part of the comments on the proposed plan have been added to the database. The current database contains in excess of 500,000 analytical records captured from every major substantial data collection activity since 1989 up until the time the proposed plan was released and covers analysis of sediment, water, air, and biota (e.g., fish and wildlife tissues).

### 6.2.3 Nature of Contamination

Contaminants representing the primary risk driver studied in the RI/FS are, by definition, polychlorinated biphenyls. PCBs consist of a group of 209 distinct chemical compounds, known as congeners, that contain one to ten chlorine atoms attached to a biphenyl molecule, with the generic formula of $C12H_{(10-x)}Cl_x$, where x is an integer from one to ten. Homologue groups are identified based on the number of chlorine atoms present. For example, monochlorobiphenyls contain one chlorine atom, dichlorobiphenyls contain two chlorine atoms, and trichlorobiphenyls contain three chlorine atoms. Some PCB congeners are structurally and toxicologically similar to dioxin (sometimes called dioxin-like PCBs).

Commercially manufactured PCBs consisted of complex mixtures of congeners, known under various trade names. These PCBs were marketed under the general trade name “Aroclors.” About 140 to 150 different congeners have been identified in the various commercial Aroclors, with about 60 to 90 different congeners present in each individual Aroclor.

The polychlorinated biphenyls (PCBs) used in the production of carbonless copy paper by paper manufacturing facilities on the Fox River from 1954 to 1971, consisted largely of the Aroclor identified as “1242.” Carbonless copy paper produced during this time contained approximately 3.4 percent PCBs by weight.

Other contaminants of potential concern (e.g., mercury, lead, arsenic, dieldrin, DDT/DDE/DDD, furan, and dioxin) are also present, but are not significant risk drivers due to relatively low concentrations.

**Sources**

Twenty paper mills are located along the portion of the Fox River included in the Site. Among that group of companies, six engaged in the production or de-inking of carbonless copy paper containing PCBs. As a result of those processes, these mills discharged PCBs to the Lower Fox River. It is estimated that the wastewater discharged by the paper mills either directly or indirectly (through publicly owned treatment works) into the Fox River released an estimated 690,000 pounds of PCBs into the Lower Fox River.

**Contaminated Media**

<u>Sediment</u>
Much of the volume of PCBs discharged into the Lower Fox River in the past has already been transported throughout the system and is now concentrated in sediment within specific areas. In general, the upper three River reaches can be characterized as having discrete soft sediment deposits within inter deposit areas that have little or no soft sediment. In contrast, the last River reach from De Pere to Green Bay is essentially one large, continuous soft sediment deposit. Because there were several points of PCB discharge along the entire length of the Lower Fox River, PCB concentrations and mass distributions are highly variable. Table 1 summarizes the distribution of PCBs within OU 1 and OU 2 sediments.

**Table 1 PCB Distribution in the Lower Fox River OUs 1 and 2**

| River Reaches | Sediment Volume (cy) | PCB Mass (kg) | PCB Mass in Top 100 cm (%) |
|---|---|---|---|
| OU 1- Little Lake Butte des Morts | 2,200,400 | 1,849 | 98% |
| OU 2 - Appleton to Little Rapids | 339,200 | 109 | 100% |

<u>Transport of PCBs in Fox River</u>
Contaminant fate and transport in the Lower Fox River and Green Bay are largely a function of deposition, suspension, and redeposition of the Chemicals of Concern (COC) that are bound to sediment particles. The organic COCs (PCBs, pesticides) exhibit strong affinities for organic material in the sediment. The ultimate fate and transport of these organic compounds depends significantly on the rate of flow and water velocities through the River and Bay. More sediment becomes suspended and transported downstream during high-flow events like storms and spring snowmelt. High-flow events occur approximately 15 to 20 percent of the time, but can transport more than 50 to 60 percent of the PCB mass that moves annually. In any event, less than 1 kilogram/year enters Little Lake Butte des Morts from Lake Winnebago and 40 kilograms (88 pounds)/year are resuspended and transported from Little Lake Butte des Morts to OU 2

(Little Rapids Reach). An estimated 64 kilograms (141 pounds)/year migrate from OU 2 downstream. This estimate does not consider removal of the Deposit N or for possible actions for Deposit DD. Other modes of contaminant transport, such as volatilization, atmospheric deposition, and point source discharges, are negligible when compared to sediment resuspension.

Changes in Sediment Bed Elevation

The Lower Fox River is an alluvial river that exhibits significant changes in bed elevations over time in response to changing volumes of flow during annual, seasonal, and storm events, changes in sediment load, and changes in its base level, which is determined by Lake Michigan. Sediment in the riverbed is dynamic and does not function as discrete layers. River sediment movement is in marked contrast to the sediment dynamics found in a large quiescent body of water, such as deep lakes, or the deeper portions of Green Bay. Scouring of the sediment bed plays a significant role in the quantity of sediment and contaminants transported through the River system. In response to comments received from the FRG on the 1999 draft RI/FS to the effect that less than one inch of sediment would be resuspended from the riverbed as a result of a 100-year storm event, WDNR and EPA investigated changes in sediment bed elevation for the De Pere to Green Bay River reach (OU 4). This work is partially relevant to OU 1 and OU 2, but is informative regarding movement of Fox River sediments generally. This work (see Technical Memo 2g of the Model Documentation Report) was completed by a group called the FRG/WDNR Model Evaluation Workgroup as part of the 1997 agreement between the FRG and WDNR. Additional evaluation by EPA was consistent with changes documented in Technical Memo 2g.

Results of these analyses indicate that sediment bed elevation changes occur in the Lower Fox River over both short- and long-term time frames. Changes in sediment bed elevation were observed both across the channel and downstream profiles. These changes show little continuity. Since River flows have not significantly changed in recent years, the complexity of these sediment bed elevation changes reflects the prevailing hydrologic and sediment conditions that occurred over a 22-year period from 1977 through 2000. The wide range of discharges and sediment loads continuously reshapes the Lower Fox River sediment bed. Short-term (e.g., annual and sub-annual) changes in average net sediment bed elevations range from a decrease or scour of over 11 inches to an increase or deposition of over 14 inches. Long-term (e.g., over several years) changes in average net elevations range from a decrease of more than 39 inches to an increase of nearly 17 inches. The changes documented are well supported by U.S. Army Corps of Engineers (USACE) sediment volume calculations from pre- and post-dredge sediment bed elevation surveys, as well as by results of a U.S. Geological Survey (USGS) analysis of bed surveys performed at intermediate time scales (e.g., 8 months to 45 months).

Surveys of the River bottom, conducted by several different groups, show significant changes in sediment bed elevation. On average, sediment bed elevation data from throughout the De Pere to Green Bay reach suggest that this River reach is a net depositional zone. However, when examined at a finer scale, the data show areas of sediment scour up to 14 ft. It should be noted that during the survey period, there were no large storm events of a 10-year or greater magnitude. It is unknown what the scour would be during larger events.

For OUs 1 and 2, PCBs are often high in surficial sediments. This is indicative that higher concentrations of PCBs continue to be exposed or re-exposed.

<u>The Potential for Natural Biodegradation of PCBs</u>

Responding to comments received from the EPA's peer review panel concerning natural recovery, the viability of natural degradation as a potential remedial action for the sediment-bound PCBs in the Lower Fox River and Green Bay was evaluated. Two basic processes, both anaerobic (without oxygen) and aerobic (in the presence of oxygen) degradation, must occur to completely decompose PCBs. Based on evidence in the literature, anaerobic PCB degradation was demonstrated to have occurred under field conditions at almost all the sites studied. However, a reduction in PCB concentrations through anaerobic processes is site-dependent. In the Lower Fox River, University of Wisconsin researchers found only a 10 percent reduction that could be attributed to anaerobic degradation processes in deposits with average PCB concentrations greater than 30 mg/kg. More importantly, no PCB reductions resulting from anaerobic processes could be accounted for in deposits with average concentrations less than 30 mg/kg.

Other active treatment options might possibly promote dechlorination of the sediment, making the PCBs more amenable to biological destruction. However, a pilot-scale experiment conducted at the Sheboygan River, another site with PCB-contaminated sediment, yielded inconclusive results regarding the viability of enhanced biodegradation. In that study, PCB-contaminated sediment was removed from the River and placed into a specially engineered treatment facility. The sediment was seeded with microorganisms and nutrients and the sediment was manipulated between aerobic and anaerobic conditions to optimize biological degradation. Even under these conditions, the data were insufficient to conclude that PCB decomposition was enhanced.

<u>Effects of Time</u>

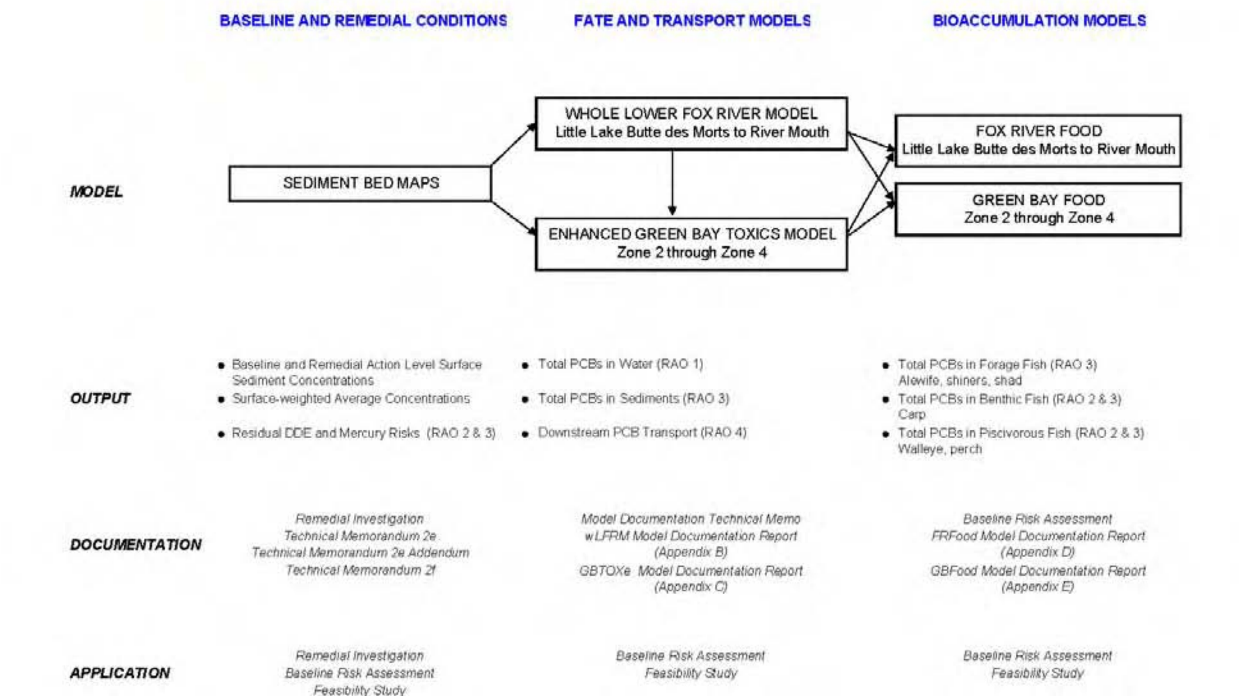
The Fox River Database includes sediment and water test results for tissue samples collected since 1971. During the 1970s, after PCB use in the manufacturing of carbonless copy paper had ceased, PCB concentrations in fish tissue showed significantly declining concentrations. Since the mid-1980s, however, changes in PCB levels in fish have slowed, remained constant, or, in some cases, increased.

Trends in PCB concentrations in the surface layer (i.e., top four inches) of River sediment are not consistent, but concentrations generally appear to be decreasing over time as more PCB mass is transported downstream. However, the time trends showed that concentrations in the subsurface sediments do not appear to be declining. This indicates that a considerable amount of PCB mass remains within the sediments of the Lower Fox River. Any changes made to the current lock and dam configuration on the River could result in increased scour and resuspension of those underlying sediments, which could in turn result in increases in fish tissue concentrations. In addition, soil eroded from the watershed mixes with and may further dilute PCB concentrations in the sediment.

<u>Modeling Effort for the Lower Fox River</u>

Four interrelated models were used in the RI/FS to simulate the fate and transport of PCBs in the Lower Fox River and Green Bay (Figure 4). They are mathematical representations of the transport and transfer of PCBs between the sediment, the water, and uptake into the River and Bay food webs. The models are intended not only to provide information on the fate and transport of PCBs in an unremediated River system, but also to compare the potential remedial alternatives in the FS. The models tend to estimate concentrations lower than the concentrations actually observed in the River. The relative differences predicted by the model are considered to be reliable.

**Figure 4 Relationship of Models Used for Risk Projections in the Lower Fox River and Green Bay**




The modeling effort included:

- Bed mapping of the Lower Fox River to define sediment thickness, sediment physical properties (such as total organic carbon and bulk density), and total PCB concentrations;
- Use of the whole Lower Fox River Model (wLFRM) to simulate the movement of PCBs in the water column and sediment of the Lower Fox River from Little Lake Butte des Morts to the mouth of the River at Green Bay; and,
- Use of the Fox River Food Chain Model (FRFOOD) to simulate the uptake and accumulation of PCBs in the aquatic food chain in the Lower Fox River using model results from wLFRM.

Bed mapping provided the foundation for the modeling inputs. Total PCB concentrations in surface sediment for the baseline and action levels serve as inputs to wLFRM . This model projects total PCB concentrations in water and sediment. The output from this model is in turn used in the bioaccumulation model, FRFood, to project whole fish tissue concentrations of PCBs (Figure 4). The output from all of the models is then compared to the remedial action levels specified in the FS. This information is used in the FS to estimate the length of time it would take for a receptor to achieve the acceptable fish tissue concentration in response to a given action level.

Taken together, these models provide a method for evaluating the long-term effects of different remedial alternatives and different action levels on PCB concentrations in water, sediment, and aquatic biota in the Lower Fox River. The models are then used to predict PCB concentrations in the aquatic environment over a 100-year period under different remedial alternatives and action levels. The modeling results are discussed in the FS, and a more detailed discussion on modeling can be found in the Model Documentation Report. A complete copy of that report is available on the WDNR's Lower Fox River Web page.

<u>Water Column</u>
The dominant current PCB source to the water column is sediments. Average River surface water total concentrations are 54.6 parts per trillion (ppt), with particulates and dissolved concentrations, 40.0 ppt and 14.6 ppt, respectively. There are significant seasonal variations, particularly when the water temperature drops below 40$^{o}$ F. For example during the winter months of December 1994 and February 1995, total PCB concentrations dropped to about 10 percent of the average concentration. Average Green Bay concentrations range from 18.5 ppt for zone 2 to non-detect in zone 4.

<u>Fish and Other Biota</u>
PCB concentrations in fish are a result of the fish's exposure to PCBs in water and surface sediment, through an aquatic food chain and/or a benthic food chain, respectively. WDNR continues to collect and analyze fish tissue data from locations in the Fox River and Green Bay.

A wide variety of fish and other species have been collected and analyzed for the Fox River and Green Bay from 1971 to present. Generally, concentrations in biota have been declining, although the rate of decline varies depending upon the location and time.

<u>Air</u>
PCBs can enter the air via volatilization from PCB-contaminated water and soil although volatilization of PCBs is generally considered to be limited. Air monitoring during the 1999 SMU 56/57 dredging project demonstrated that even under "worst case" conditions (i.e., when sediments are excavated and exposed to the air) that volatilization of PCBs do not pose a significant risk to humans or wildlife.

### 6.2.4 Geochemistry and Modeling Conclusions

In the RI/FS, EPA evaluated PCB contamination at the Site using a number of tools. These tools include geochemical analyses of the water and sediment, "time trends" (i.e., statistical) analyses, and analysis of biological monitoring data, and synthesis of the data by the application of a set of complex mathematical (i.e., computer) models. PCB physical/chemical transport and fate and PCB bioaccumulation models were applied to predict future levels of PCBs in the Fox River and Green Bay sediment, water and fish.

## 7. CURRENT AND POTENTIAL FUTURE SITE AND RESOURCE USES

As one of Wisconsin's great rivers, the Lower Fox River has played and will continue to play a major role in the history, culture, and economy of the area. The Fox River has played an important role in defining regional history and culture. Current and reasonably anticipated future land use and surface water use are described below.

### 7.1 Current and Reasonably Anticipated Future Land Use

Current land use includes a variety of residential, commercial, agricultural, and industrial activities. Use of the River and lands surrounding the River are projected to remain the same. At this time, no changes in future land use are known, nor are any new uses expected. Table 2 below summarizes current land use for OUs 1 and 2.

**Table 2 Predominant Land Use by Operable Unit**

| Operable Unit | Predominant Land Use |
|---|---|
| 1 - Little Lake Butte des Morts | Residential, industrial, and commercial |
| 2 - Appleton to Little Rapids | Residential, industrial, commercial, and agricultural |

Other uses of the River include parks, woodlands, and recreational. OUs 1 and 2 pass through Winnebago, Outagamie and Brown Counties.

## 7.2 Surface Water Uses

- *Industrial and commercial purposes:* Uses include generation of electrical power and industrial/commercial purposes.
- *Residential/Domestic:* Due to historic problems in the Lower Fox River, the main surface water sources for human consumption for the areas surrounding OU 1 and 2 is Lake Winnebago and groundwater (i.e., not the Fox River).
- *Recreation:* The Fox River supports a variety of water-based recreational activities including sport fishing, waterfowl hunting, swimming and boating. Boating (both power and non-power) is available on the River, particularly in Little Lake Butte des Morts. Tourism is popular and important to the local economy.
- *Ecological Resources:* The Fox River and Green Bay support many species of birds (e.g., tree swallow, Forsters and Common Tern, Double-crested Cormorants, Bald Eagles) fish (Rainbow Smelt, Alewife, Gizzard Shad, Shiner, Yellow Perch, Carp, Brown Trout and Walleye), and mammals (e.g., mink), including sixteen (16) species of State or federally listed Threatened or Endangered species.

The Lower Fox River provides diverse habitats for all trophic levels of the River and Bay ecosystem. Plants, plankton, aquatic invertebrates, fish, amphibians, reptiles, birds and mammals use the Fox River for feeding, reproduction and shelter. In addition to the aquatic communities associated with the River, animals living in wetlands, floodplains and upland communities are also dependent on the River.

Both federal and state freshwater wetlands exist in the Fox River region, providing valuable habitat.

# 8. SUMMARY OF SITE RISKS

Baseline human health and ecological risk assessments were conducted to evaluate the potential for current and future impacts of site-related contaminants on receptors visiting, utilizing or inhabiting the Fox River and Green Bay in the Baseline Human Health and Ecological Risk Assessment (BLRA). The BLRA for the Lower Fox River and Green Bay was prepared as a companion document to the RI/FS and was finalized in December 2002.

In the portion of the report covering Human Health Risk Assessment (HHRA), cancer risks and non-cancer health hazards were evaluated for the Lower Fox River and Green Bay. In the Ecological Risk Assessment (ERA) portion of the report, ecological risks were evaluated for Lower Fox River and Green Bay. The BLRA supports the selected remedy.

The BLRA concludes that:

- Human health and ecological receptors are at risk in each Operable Unit.
- Fish consumption is the exposure pathway representing the greatest level of risk for human and ecological receptors, other than the direct risks posed to benthic invertebrates via direct exposure to contaminated sediments.
- The primary contaminant of concern is PCBs.

## 8.1 Identification of Chemicals of Concern

The Site includes the contaminated sediment found within the Lower Fox River and Green Bay. A Screening Level Risk Assessment (SLRA) was conducted to evaluate which chemicals in the system pose the greatest degree of risk to people and animals. Identified Chemicals of Concern (COCs) include PCBs, dioxins/furans, the pesticide DDT and its metabolites (DDD and DDE), the pesticide dieldrin, and arsenic, lead, and mercury.

## 8.2 Human Health Risk Assessment

### 8.2.1 Summary of Site Risks

The site-specific HHRA evaluated both cancer risks and non-cancer health hazards from exposure to PCBs in the Fox River and Green Bay, as documented in the Remedial Investigation and Feasibility Study (RI/FS). This discussion emphasizes cancer risks and non-cancer health hazards due to PCBs in the Fox River and Green Bay that exceed EPA's goals for protection. For cancer, regulatory decisions are made ranging from risk levels of one in a million ($10^{-6}$) to one in 10,000 ($10^{-4}$). A one in a 100,000 cancer risk level is commonly used in federal and state regulatory decisions. For non-cancer, a hazard index (HI) of 1 is the most frequent basis for risk management decisions. Cancer risks and non-cancer hazard indices in Green Bay were calculated to be generally similar to the Fox River. The cancer risk and non-cancer hazard indices in the Fox River and Green Bay are above EPA's levels of concern for fish consumption. Consistent with Superfund policy and guidance, the Human Health Risk Assessment (HHRA) is a baseline risk assessment and therefore assumes no actions (i.e., remediation) to control or mitigate hazardous substance releases and no institutional controls, such as the fish consumption advisories and fishing restrictions that are currently in place, which are intended to control exposure to hazardous substances. Cancer risks and non-cancer hazard indices were calculated based on an estimate of the reasonable maximum exposure (RME) expected to occur under current and future conditions at the Site. The RME is defined as an upper end exposure that is reasonably expected to occur at a Site. EPA also estimated cancer risks and non-cancer hazard indices based on central tendency (CT), or average, exposures at the Site. For both the RME and CT exposures, average contaminant (e.g., PCBs) levels in fish were exceeded. The following discussion summarizes the HHRA with respect to the basic steps of the Superfund HHRA process: 1) Data Collection and Analysis, 2) Exposure Assessment, 3) Toxicity Assessment and 4) Risk Characterization.

### 8.2.2 Data Collection and Analysis

The HHRA utilizes documents relating to the nature and extent of PCB contamination at the Site developed as part of the RI/FS. These RI/FS documents provide both current and projected future concentrations of PCBs in air, fish, sediments and river water. To calculate cancer risks and non-cancer hazard indices, the information on concentrations in these media (Tables 3 and 4) are combined with other information on exposure (see Section 8.2.3) and toxicity (see Section 8.2.4).

**Table 3 Summary of PCB Data and Medium-Specific Human Exposure Point Concentrations for OU 1**

| Exposure Point | Chemical of Concern | | Concentration Detected | | Frequency of Detection | Exposure Point Concentration (ppm) | Statistical Measure |
|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | | | |
| Sediments | Total PCBs | | 0.002 ppm | 222.7 ppm* | 539/661 | 3.70 | mean |
| Surface Water Direct Contact | Total PCBs | particulate | 0.13 ng/L | 40.16 ng/L | 34/41 | 1.66E-05 | mean |
| | | dissolved | 1.4 ng/L | 19 ng/L | 40/46 | 1.11E-05 | |
| Fish Tissue (Walleye) | Total PCBs | | 0.0989 ppm | 3.8 ppm | 11/13 | 1.16 | mean |

*ng/L - nannograms/Liter*
*ppm - parts per million*
**data submitted with comments from the responsible parties included data from LLBdM in excess of 360 ppm PCB.*

*Data sources:*
*Concentrations and detections for surface water -- RI Tables, 5-1, 5-16 and RA Table 6-14.*
*Point of exposures -- RA Table 5-31, 6-8.*

**Table 4 Summary of PCB Data and Medium-Specific Human Exposure Point Concentrations for OU 2**

| Exposure Point | Chemical of Concern | | Concentration Detected | | Frequency of Detection | Exposure Point Concentration (ppm) | Statistical Measure |
|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | | | |
| Sediments | Total PCBs | | 0 ppm | 77.444 ppm | 188/263 | 1.40 | mean |
| Surface Water Direct Contact | Total PCBs | particulate | 0.01 ng/L | 52.17 ng/L | 34/41 | 1.19E-05 | mean |
| | | dissolved | 0.026 ng/L | 18.86 ng/L | 84/85 | 4.84E-06 | |
| Fish Tissue (Walleye) | Total PCBs | | 1.431 ppm | 3.90 ppm | 4/4 | 2.74 | mean |

*ng/L - nannograms/Liter*
*ppm - parts per million*
*Data sources:*
*Concentrations and detections for surface water -- RI Tables, 5-1, 5-16 and RA Table 6-14.*

Fish at the Site have been collected by the WDNR for approximately 35 years, with fish advisories in effect since 1976. Fish samples have been analyzed for PCBs (both total PCBs and selected congeners), Dioxins/furans (specifically, 2,3,7,8-TCDD and 2,3,7,8-TCDF), DDT (dichlorodiphenyltrichloroethane), a pesticide, and its metabolites (DDD and DDE) Dieldrin (pesticide), arsenic, lead and mercury. These non-PCB contaminants were found to present substantially less risk compared to PCBs. Additionally, some of the other contaminants identified in sediment have similar fate and transport properties, and are generally found with PCBs. For this reason, a remedy that effectively addresses PCB exposure will also address the other COCs (with lesser toxicities) in the sediment.

The conceptual site model identifies potential receptors for COCs and exposure pathways. As discussed above, determination of PCB exposure provides a sound basis for characterizing significant human health risks at the Site. Estimates of the exposures allow a quantitative risk evaluation. This was done for fish, sediment, drinking/river water, and air. Most Site risks were determined to relate to fish consumption, with only minimal risk associated with other potential exposures (e.g., inhalation, direct contact). Thus the discussion below focuses on risks and exposures related to fish consumption.

Specifically, these quantitative risk calculations from fish consumption were based on wet-weight PCB concentrations in fish fillets, as generated by WDNR's bioaccumulation models, Fox River Food (FRFOOD) and Green Bay Food (GBFOOD). The fillet represents the portion of the fish most commonly consumed. The fish exposures were derived by weighting the model output by reported angler preference for species consumption (i.e., weighting the modeled PCB concentrations in fish to reflect the species caught and consumed by anglers) and by averaging over location within the study area.

### 8.2.3 Exposure Assessment

The exposure assessment evaluates exposure pathways by which people are or can be exposed to the contaminants of concern in different media (e.g., fish, water, and sediment). Factors relating to the exposure assessment include, but are not limited to, the concentrations that people are or can be exposed to and the potential frequency and duration of exposure.

Conceptual Site Model
Human exposure to PCBs through consumption of fish presented the greatest risk. Other human exposure pathways such as inhalation, drinking contaminated water or direct exposure presented no significant risk. The human health conceptual site model is shown in Figure 2.

Exposed Populations
Recreational and high intake (i.e., subsistence) fish consumers are the most likely population to have significant PCB exposures. Populations that may have portions of their members engaged in subsistence fishing include Native Americans, and Hmong (Laotians). Sensitive populations that were qualitatively evaluated include highly exposed (i.e., subsistence) anglers and their families as well as infants of mothers who ingest fish that are exposed *in utero* and/or through consumption of breast milk. With respect to subsistence or highly exposed angler populations in Wisconsin, review of the literature suggests that these populations are likely to be adequately represented in the HHRA. With respect to infants (less than one year old), exposure to PCBs *in utero* and via ingestion of breast milk are known exposure routes that pose risks to fetal development in the infant. Several ongoing studies are determining if it is possible to develop quantitative relationships between fetal/infant PCB exposure and developmental effects. Standard EPA default factors were used for angler body weight [e.g., 72 (kilograms (kgs) for an adult].

Fish Ingestion Rate
Several fish consumption surveys were used to evaluate fish intake rates for both recreational and high intake fish consumers. Specific studies included: West (1989, 1993) conducted in Michigan; Fiore (1989) conducted in Wisconsin; Hutchinson and Kraft conducted in Wisconsin (1994) and Hutchinson (1999) conducted in Wisconsin. The RME fish ingestion rate was determined to be 59 grams per day from the West studies while 81 grams was determined for high intake fishes, using the findings from Hutchinson and Kraft (1994).

Exposure Duration
Values of 30 years for Central Tendency Exposure (CTE) and 50 years for the RME scenario were established based on EPA published estimates of the years persons live in the Lower Fox River and Green Bay area.

PCB Cooking Loss
PCB losses during cooking were assumed to be 50 percent, based on studies reported in the literature. Potential PCB loss mechanisms include removing skin and fat, draining cooking fluids from the fish and grilling to allow oil to drip away from the fish.

Probabilistic Analysis
In addition to the point estimate (i.e., deterministic) analyses, a probabilistic analysis was performed to provide a range of estimates of the cancer risks and non-cancer health hazards associated with the fish ingestion pathway. The probabilistic analysis helps to evaluate variability in exposure parameters (e.g., differences within a population's fish ingestion rates, number of years anglers are exposed, body weight, etc.) and uncertainty (i.e., lack of complete knowledge about specific variables). The deterministic risk analyses using point estimates to generate RME exposures and risks was found to compare favorably to findings from the probabilistic approach.

### 8.2.4 Toxicity

The toxicity assessment determines the types of adverse health effects associated with PCB exposures and the relationship between the magnitude of exposure (dose) and severity of adverse effects (response). Potential health effects for PCBs include the risk of developing cancer over a lifetime. Other non-cancer health effects, such as changes in the normal functions of organs within the body (e.g., changes in the effectiveness of the immune system), are also associated with PCB exposure. Some of the 209 PCB congeners are considered to be structurally and mechanistically similar to dioxin and exert dioxin-like effects.

Sources of Toxicity Information.
The HHRA used the current consensus toxicity values for PCBs from EPA's Integrated Risk Information System (IRIS) in evaluating the cancer risk and non-cancer health effects of PCBs. IRIS provides the primary database of chemical-specific toxicity information used in Superfund risk assessments. More recent toxicity data are provided in Appendix D of the BLRA. These data do not change EPA's use of IRIS values. For the dioxin-like PCBs, the HHRA used toxicity information for dioxin (2,3,7,8-TCDD) provided in EPA's 1997 Health Effects Assessment Summary Tables.

Cancer
EPA has determined that PCBs cause cancer in animals and probably cause cancer in humans (B2 classification or likely to cause cancer in humans). EPA's cancer slope factors (CSFs) for PCBs represent plausible upper bound estimates, which means that EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks calculated using the

CSFs. For fish ingestion, the pathway determined to be of greatest concern, CSFs of 2 (mg/kg day)$^{-1}$ and 1 (mg/kg-day)$^{-1}$ were used for the RME and CT (average) exposure, respectively. For dermal and inhalation exposures, a CSF of 2 (mg/kg-day)$^{-1}$ was used with a dermal absorption fraction of 14 percent, consistent with the IRIS chemical file. For inhalation, a CSF of 0.4 (mg/kg-day)$^{-1}$ was used. For the dioxin-like PCBs, the CSF for 2,3,7,8-TCDD of 150,000 (mg/kg-day) was used.

<u>Non-Cancer Health Effects</u>
Serious non-cancer health effects have been observed in animals exposed to PCBs. Studies of Rhesus monkeys exposed through ingestion of PCBs (i.e., Aroclors 1016 and 1254) indicate a reduced ability to fight infection and reduced birth weight in offspring exposed *in utero*. Studies of non-cancer health effects, including neurobehavioral effects observed in children of mothers who consume PCB-contaminated fish were summarized in the baseline risk assessment and~~,~~ are being evaluated by EPA as part of the Agency's IRIS process. The toxicity assessment is an evaluation of the chronic (e.g., 7 years or more) adverse health effects from exposure to PCBs. The chronic Reference Dose (RfD) represents an estimate (with uncertainty spanning an order of magnitude or greater) of a daily exposure level for the human population, including sensitive populations (e.g., children), which is likely to be without an appreciable risk of deleterious effects during a lifetime. Chemical exposures exceeding the RfD do not predict specific disease. For the fish ingestion pathway, the oral RfD for Aroclor 1254 of 2 x $10^{-5}$ mg/kg-day was used for the RME and CT (average) exposures, because the congener analysis of fish samples more closely resembled Aroclor 1254 rather than 1016. For the sediment and water ingestion pathways, the oral RfD for Aroclor 1016 of 7 x $10^{-5}$ mg/kg-day was used because analyses of sediment and water samples most closely resemble Aroclor 1016. For the dermal contact pathway, dermal RfDs were extrapolated from the oral RfD for Aroclor 1016.

### 8.2.5 Risk Characterization

This final step in the HHRA combines the exposure and toxicity information to provide a quantitative assessment of site risks. Exposures are evaluated based on the potential risk for developing cancer and the potential for non-cancer health hazards.

### 8.2.6 Cancer Risks

Cancer risk is expressed as a probability. For example, a $10^{-4}$ cancer risk means a one in 10,000 excess cancer risk, or an increased risk of an individual developing cancer of one in 10,000 as a result of exposure to site contaminants under the conditions used in the Exposure Assessment. Under Superfund, acceptable exposures RME cancer risk must be defined with the range of $10^{-4}$ to $10^{-6}$ (corresponding to a one in 10,000 to a one in 1,000,000 excess cancer risk). Excess lifetime cancer risk is calculated from the following equation:

$$Risk = CDI \times CSF$$

where: Risk = a unit less probability (e.g., 1 x $10^{-3}$ of an individual developing cancer)

CDI = Chronic Daily Intake averaged over 70 years (mg/kg-day)
CSF = Cancer Slope Factor, expressed as (mg/kg-day)$^{-1}$

At this Site, cancer risks to the RME individual associated with ingestion of fish are above EPA's generally acceptable levels, as shown below in Tables 5 and 6. In addition, cancer risks to the average (CT) individual associated with ingestion of fish are above EPA's goal for protection. Tables 5 and 6 below summarize key cancer risks from Tables 5-82 and 5-86 from the Human Health Risk Assessment for the Site. Cancer risks from exposure to dioxin-like PCBs were comparable to the cancer risks from the non-dioxin-like PCBs presented below for fish ingestion.

**Table 5 Cancer Risk from Fish Ingestion – Summary for OU 1**

| Pathway | RME Cancer Risk | CT (Average) Cancer Risk |
|---|---|---|
| Recreational Angler | | |
| All Fish | $5.2 \times 10^{-4}$ (5.2 in 100,000) | $7.8 \times 10^{-5}$ (7.8 in 100,000) |
| Walleye | $1.5 \times 10^{-4}$ (1.5 in 10,000) | $2.2 \times 10^{-5}$ (2.2 in 100,000) |
| High Intake (i.e., Subsistence) Angler | | |
| All Fish | $7.2 \times 10^{-4}$ (7.2 in 10,000) | $1.1 \times 10^{-4}$ (1.1 in 10,000) |
| Walleye | $2.0 \times 10^{-4}$ (2.0 in 10,000) | $3.2 \times 10^{-5}$ (3.2 in 100,000) |

**Table 6 Cancer Risk from Fish Ingestion – Summary for OU 2**

| Pathway | RME Cancer Risk | CT (Average) Cancer Risk |
|---|---|---|
| Recreational Angler | | |
| All Fish | $4.9 \times 10^{-4}$ (4.9 in 10,000) | $7.4 \times 10^{-5}$ (7.4 in 100,000) |
| Walleye | $1.6 \times 10^{-4}$ (1.6 in 10,000) | $2.4 \times 10^{-5}$ (2.4 in 100,000) |
| High Intake (i.e., Subsistence Angler) | | |
| All Fish | $6.8 \times 10^{-4}$ (6.8 in 10,000) | $1.1 \times 10^{-4}$ (1.1 in 10,000) |
| Walleye | $2.3 \times 10^{-4}$ (2.3 in 10,000) | $3.5 \times 10^{-5}$ (3.5 in 100,000) |

### 8.2.7 Non-Cancer Health Hazards

The potential for non-cancer health effects is evaluated by comparing an exposure level over a specified time period (e.g., 7 years) with Reference Dose (RfD) derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a Hazard Quotient (HQ). An HQ less than 1 indicates that a receptor’s dose of a single contaminant is less than the RfD, and that toxic non-carcinogenic effects from that chemical are unlikely. A Hazard Index (HI) represents the sum of the individual exposure levels for different chemicals and different media (e.g., fish, water, sediment) compared to their corresponding RfDs (i.e., HI is the sum of HQs for an individual). The key concept of a non-cancer HI is that a threshold level (measured as an HI of 1) exists below which non-cancer health effects are not expected to occur. Under the federal Superfund program, EPA’s goal for protection for non-cancer health hazards is an HI equal or less than 1 for the RME individual.

The HQ is calculated as follows:

$$\text{Non-cancer HQ} = \text{CDI}/\text{RfD}$$

where: CDI = Chronic daily intake (mg/kg-day)
RfD = Reference dose (mg/kg-day)

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic).

At this Site, all non-cancer RME hazard indices from the consumption of PCBs in fish are above EPA’s generally acceptable levels, as shown below (see also Table 6). Risk to children is particularly elevated. Tables 7 and 8 below summarize key non-cancer risks from Tables 5-84, 5-85, from the Human Health Risk Assessment for the Site. In addition, non-cancer hazard indices to the average (CT) individual are above EPA's generally acceptable levels. Non-cancer hazard indices for dioxin-like PCBs were not evaluated quantitatively due to EPA's ongoing evaluation of dioxin toxicity.

**Table 7 Non-Cancer Health Hazard from Fish Ingestion – Summary for OU 1**

| Pathway | RME Non-Cancer HI | CT (Average) Non-Cancer HI |
|---|---|---|
| **Recreational Angler** | | |
| All Fish | 20 | 5 |
| Walleye | 5.5 | 1.4 |
| **High Intake (i.e., subsistence) Angler** | | |
| All Fish | 27 | 7 |
| Walleye | 8 | 2 |
| **High Intake Recreational Child** | | |
| All Fish | 47 | 12 |
| Walleye | 13 | 3 |
| **High Intake Subsistence Child** | | |
| All Fish | 65 | 17 |
| Walleye | 19 | 5 |

**Table 8 Non-Cancer Health Hazard from Fish Ingestion – Summary for OU 2**

| Pathway | RME Non-Cancer HI | CT (Average) Non-Cancer HI |
|---|---|---|
| Recreational Angler | 84 | 21 |
| High Intake (i.e., subsistence) Angler | 115 | 30 |

### 8.2.8 Probabilistic Analysis

In addition to the deterministic calculations discussed above, EPA calculated risks for ingestion of fish in the Fox River and Green Bay using a probabilistic analysis, consistent with EPA guidance on probabilistic risk assessments (EPA, 1999). This analysis supports and complements the point estimates of risks and hazard indices calculated in evaluations of exposure to PCBs in fish.

Deterministic RME estimates of risk and hazard index provided in the probabilistic evaluation are generally consistent within the $90^{th}$ to $95^{th}$ percentiles of the respective probability distributions of risk and hazard indices. This is consistent with the interpretation provided by EPA (EPA, 1999) of the RME as a plausible high-end risk or hazard index for the exposed population.

Deterministic CTE estimates of risk and hazard index are generally close to the means of probability distributions of risk and hazard index. This is consistent with the interpretation of the CTE as the average risk or hazard index for the exposed population.

### 8.2.9 Uncertainty

The process of evaluating human health cancer risks and non-cancer hazard indices involves multiple steps. Inherent in each step of the process are uncertainties that ultimately affect the final cancer risks and non-cancer hazard indices. Important sources of uncertainty in the HHRA are discussed below:

The use of a bioaccumulation model to generate future concentrations of PCBs in fish if no action occurs were used in the HHRA calculations. WDNR minimized this uncertainty to the extent possible by developing a bioaccumulation model specifically for the Fox River Fox River and Green Bay (i.e., “FRFOOD” and “GBFOOD”, respectively), calibrating the model to the extensive database for the Fox River and Green Bay. Additionally the model was revised based on a peer review sponsored by the Fox River Group. Based on the model calibration (i.e., the ability of the fish bioaccumulation model to capture the historical observed lipid-normalized PCB measurements in fish), and the feedback received from the peer review, the model uncertainty is not sufficient to change the overall conclusion of the HHRA that cancer risks and non-cancer hazard indices due to ingestion of fish are above acceptable levels.

<u>Time Trends</u>
Although concentrations in fish may be decreasing over time for some fish species in OU 1 and OU 2 these trends were not consistent with all species. In addition, trends in the surficial sediment layer are not consistent and concentrations in deeper sediments are not decreasing. Additionally, events that may scour sediments may cause declining trends currently observed to either slow or reverse.

<u>Fish Ingestion Rate</u>
This uncertainty in the fish ingestion rate was minimized by relying on a number of surveys. These included Michigan angler surveys for recreational anglers by West *et al.*, 1989 and 1993, and a Wisconsin angler survey by Fiore, 1989. For high intake fish consumers, surveys by West *et al.*, 1993, Peterson, 1994 and Hutchison and Kraft, 1994, Hutchison, 1994, and Hutchison, 1999 were also considered. In addition, the sensitivity/uncertainty analysis conducted for the probabilistic analysis showed that, despite the use of different fish, the overall conclusion of the HHRA -- that cancer risks and non-cancer hazard indices due to ingestion of fish are above levels of concern, essentially remains the same.

<u>PCB Toxicity</u>
EPA describes the uncertainty in the cancer toxicity values as extending in both directions (i.e., contributing to possible underestimation or overestimation of cancer slope factors (CSF)). However, the CSFs were developed to represent plausible upper bound estimates, which means that EPA is reasonably confident that the actual cancer risk will not exceed the estimated risk calculated using the CSF. The CSFs used in the HHRA were externally peer reviewed and supported by the panel of expert scientists and are the most current values recommended by EPA in IRIS. Non-cancer toxicity values also have uncertainty. The current oral RfDs for Aroclor 1016 and 1254, which were used in the HHRA, have uncertainty factors of 100 and 300, respectively in order to provide for protection of public health. The RfD for Aroclor 1016 was externally peer-reviewed and supported by the panel of scientists. The RfD for Aroclor 1254 was developed using the same methodology as Aroclor 1016 and was internally peer-reviewed. Since these RfDs were developed, a number of recent national and international studies have reported possible associations between developmental and neurotoxic effects in children from prenatal or postnatal exposures to PCBs. In light of these new studies, the current RfDs are currently being evaluated as part of the IRIS process. It would be inappropriate to prejudge the results of the IRIS evaluation at this time.

PCB Body Burden

The fact that any previous exposures (either background or past consumption of PCB-contaminated fish) may still be reflected in an individual's body burden today is an additional source of uncertainty and may result in an underestimate of non-cancer hazard indices and cancer risks.

PCB Bioaccumulation Modeling

The use of a bioaccumulation model to generate estimations of future concentrations of PCBs in fish if no action occurs were used in the HHRA calculations. WDNR minimized this uncertainty to the extent possible by developing a bioaccumulation model specifically for the Fox River and Green Bay (i.e., FRFOOD and GBFOOD, respectively), calibrating the model to the extensive database for the Fox River and Green Bay. Additionally the model was revised based on a peer review sponsored by the Fox River Group. Based on the model calibration (i.e., the ability of the fish bioaccumulation model to capture the historical observed lipid-normalized PCB measurements in fish), and the feedback received from the peer review, the model uncertainty is not sufficient to change the overall conclusion of the HHRA that cancer risks and non-cancer hazard indices due to ingestion of fish are above acceptable levels.

## 8.3 Ecological Risk Assessment

The Lower Fox River and Green Bay provide habitat function for a variety of invertebrates, fish, birds, and mammals that inhabit or use this watershed for foraging, reproducing, rearing young and other life cycle requirements. The Lower Fox River basin and Green Bay varies considerably in its potential to provide and support different kinds of wildlife habitat and this variability affects the wildlife diversity and populations. The BLRA focuses primarily on aquatic, or aquatic-dependent species. Aquatic habitats within the area are wetland (e.g., Lower Fox River and Southern Green Bay), and riverine (e.g., Lower Fox River).

The significant groups of wildlife found within these habitats include the following:

- Both pelagic and benthic aquatic invertebrate species form the primary prey in the food webs of the River and Bay. Species of oligochaetes and chironomids (e.g., worms and midges) are typically most abundant and are found throughout the Lower Fox River and Green Bay. Amphipods, crayfish, snails, and mussels are also present in the River and Bay. Zebra mussels, an exotic species, are present throughout Green Bay and the River.
- Fish of the region include salmon/trout; game fish, including walleye, yellow perch, and northern pike; and pelagic and benthic non-game fish. A discussion of the significant fish species within the study area is presented later in this section.
- Birds of the region include raptors, gulls/terns, diving birds, migratory waterfowl, passerines, shorebirds, and wading birds. A listing of the significant bird species within the study area is presented later in this section. These animals are found nesting, feeding, and living in both terrestrial and aquatic habitat environments.
- Mammals of the region include large and small game animals that generally live in open or wooded habitat, as well as fur-bearing animals that may forage or live within or near aquatic environments. The small and large game animals include rabbits, squirrels, and deer. The fur-bearing animals include beaver, red fox, mink, raccoon, muskrat, and otter. Additionally, bats feed on insects in the vicinity of Lake Winnebago and near the communities along the Fox River. Few of the mammals will be discussed in detail within this document. Mink are the principal species discussed in the BLRA.

- Reptiles and amphibians, including snakes, turtles, frogs, and toads are present in the region (Exponent, 1998). Typically, the frogs and turtles confine themselves to the wetland and near shore areas while several snake species and toads are found in association with both terrestrial and aquatic habitats. Frogs and toads that dwell in wetlands or near shore areas are fed upon by wading birds of the region.

Through the mid-1970s the population levels of fish species, such as walleye and perch, were low within the Lower Fox River and southern Green Bay ecosystems. Contaminants, along with low dissolved oxygen (DO) conditions brought about by uncontrolled and untreated wastewater dumped into the River, were believed to be a contributing factor causing low population levels. Principal species found within the system were those that could tolerate these conditions, especially bullhead and carp.

With the institution of water quality controls in the mid-1970s, contaminants and DO conditions improved. The WDNR undertook a program to reintroduce walleye into the River and Bay through a stocking program beginning in 1973. That program was very successful; self-sustaining populations of walleye now exist within the River and Bay. Recent electro-fishing catch data for walleye from De Pere dam to the mouth of the Lower Fox River are shown on Figure 2-15 of the BLRA.

In addition to walleye, a number of other species were reestablished in the Lower Fox River and Green Bay, including white and yellow perch, alewife, shad, bass, and other species. Historical anecdotal data from the Oneida tribe and more recent creel survey data from the WDNR indicate that Duck Creek and Suamico tributaries to southern Green Bay were used by numerous fish species (Nelson, 1998).

The WDNR has completed extensive fish surveys in the Lower Fox River and inner Green Bay. However, due to the numerous factors that may effect fish populations, simply reviewing and comparing the population survey results from various years is not valid. Year-to-year fish populations do not necessarily indicate whether conditions within the River/Bay are degraded or improving because other environmental, physical, or biological factors may be impacting select fish species at any given time. Selected fish surveys for the Lower Fox River have been reviewed to provide data on the types of fish present within the system at given points in time. However, no in-depth analysis of whether these population surveys indicate declining or improving conditions is included. No Green Bay fish surveys are included in this discussion. Rather, the personal observations from WDNR and MDNR personnel familiar with both the commercial and sport fisheries of Green Bay are used.

### 8.3.1 Screening Ecological Risk Assessment

The Screening Ecological Risk Assessment (SERA) for the Lower Fox River and Green Bay focused on the potential for ecological risks associated with chemicals in sediments, surface waters, and biota. The SERA was conducted using conservative exposure and effects scenarios in an effort to identify which of the over 300 contaminants previously identified potentially posed risks to ecological receptors. Data from 16 separate comprehensive studies conducted on the Fox River and Green Bay by state, federal, university, and private parties were used to assess risk. The objective of the screening was to identify a smaller list of contaminants that would be carried through to the baseline risk assessment.

As defined in the Superfund Risk Assessment Guidance (EPA, 1997a), following the completion of the SERA, a Scientific Management Decision Point (SMDP) was necessary to review the results of the SERA. The technical team of risk managers and risk assessors, collectively referred to as the Biological Technical Assistance Group (BTAG), were assembled during the SERA process to specifically address SMDPs and provide technical review.

The SMDP was formalized in a memo from WDNR dated August 3, 1998 (Appendix A - RA). The memo identified and justified which chemicals should be carried forward into the RA, based on the potential for either human health or ecological risk. Of the 75 chemicals that were above screening level risk criteria, only those with the most potential for adverse risk were carried forward as BLRA contaminants of potential concern (COPCs).

The retained COPCs include: PCBs (expressed as total and PCB coplanar congeners), dioxin and furan congeners, DDT and its metabolites DDE, and DDD, dieldrin, arsenic, lead, and mercury. Sediment HQs were greatest for PCBs based on both human heath and ecological risk-based screening levels.

### 8.3.2 Baseline Ecological Risk Assessment

The overall ecological goals of the Baseline Risk Assessment (BLRA) for the Lower Fox River and Green Bay were to:

- Examine how the contaminants of potential concern (COPCs) carried forward from the Screening Level Risk Assessment (SLRA) (RETEC, 1998b) move from the sediment and water into ecological receptors within the Lower Fox River and Green Bay.
- Quantify the current (or baseline) ecological risk associated with the COPCs.
- Distinguish those COPCs, which pose the greatest potential for risk to the environment and should be carried forward as contaminants of concern (COCs) in the FS.
- Determine which exposure pathways lead to the greatest risks.
- Support the selection of a remedy, which eliminates, reduces, and/or controls identified risks by calculating sediment quality thresholds (SQTs).

Consistent with Superfund policy and guidance, the BLRA is a baseline risk assessment and, therefore, assumes no actions (remediation) to control or mitigate hazardous substance releases. The following discussion summarizes the BLRA with respect to the four basic steps of the Superfund Ecological Risk Assessment process: 1) Problem Formulation, 2) Exposure Assessment, 3) Effects Assessment, and 4) Risk Characterization.

**Problem Formulation**

<u>Chemicals of Concern</u>
PCBs were carried forward in the BLRA as the primary COPC because SLRA-calculated sediment hazard quotients (HQs) ranged from 1,514 to 5,872, generally several orders of magnitude greater than HQs for other COPCs. Although 2,3,7,8-TCDD is the most toxic dioxin congener, all structurally related dioxin and furan congeners were evaluated for toxicity based on the toxicity equivalency method, further described in Section 6.3.2 of the BLRA. The dioxin and furan congeners that will be evaluated are those that have been measured in Site media and those that have toxic equivalency factors (TEFs). The only PCB congeners that were evaluated for dioxin-like toxicity are those that most structurally resemble dioxin and have the greatest potential for bioaccumulation: congeners 77, 81, 105, 118, 126, and 169, as further discussed in Section 6.3.3 of the BLRA.

The electronic Fox River Database (FRDB) currently contains more than 500,000 records representing contaminant data from sediment, water, and tissue data. Total PCBs are the most frequently found analyte in the database. 1989 was used as a cut-off date for inclusion of data for the evaluation of risk for several reasons: 1) the contribution of these data towards assessing risk was considered to be less advantageous than the greater accuracy obtained by evaluating risk based on more current data; 2) no data collected prior to 1989 were validated, and 3) although data collected in 1989 were not validated, the total number of samples collected in this year is more than 30 percent of all samples collected.

Complete Exposure Pathways

Currently, the principal source for COPCs is the contaminated sediment deposits found throughout the system. The principal transport mechanism is sediment resuspension, with transport occurring by downstream currents in the Lower Fox River, and by discrete resuspension transport and deposition events within Green Bay (WDNR, 1998b, 1998c). The fate of these contaminants, following their release into the water column, depends on the chemical properties of the contaminant, abiotic factors within the receiving environment (e.g., organic carbon in sediments, pH, surface water hardness), and interaction with the biotic environment. This interaction can result in degradation, transformation, or bioconcentration of the contaminant. The fate of a contaminant is not fixed, and the degree of contaminant exchange between surface water, sediment, sediment pore water, and biota varies.

Aquatic organisms can be exposed to COPCs through the water column, through ingesting sediments, and through consumption of contaminated prey. Water column organisms are exposed to dissolved and particulate-based COPCs through respiration, ingestion and direct contact. Benthic invertebrates are exposed through direct contact and ingestion of contaminated sediments. Benthic fish, carnivorous birds and carnivorous mammals can incidentally ingest sediments during feeding on prey species. All of the COPCs have the potential to biomagnify up the food chain except for lead and arsenic, which can bioconcentrate. Therefore, benthic invertebrates, fish, birds and mammals are all exposed to COPCs by consuming contaminated food.

PCBs in the environment are stable and persistent; cycling rather than degradation represents the predominant fate. PCBs are highly lipophilic and, therefore, more readily bind to sediments or accumulate in tissues rather than remain in the water column. Aquatic organisms can be exposed to PCBs through the water column, through ingesting sediments, and through consuming prey. For invertebrates, both aquatic and benthic, exposure to PCBs through contact with the water column or pore water contributes significantly to the total body burden of total PCBs. For most species, however, particularly those at high trophic levels, prey consumption is likely the primary route of exposure. Biological uptake of PCBs by aquatic organisms appears to be species-specific. Rates of accumulation vary depending on species, age, sex, and size. Generally, when equally exposed, fish accumulate two to three times more PCBs than aquatic invertebrates.

Bioaccumulation of non-polar organic compounds occurs as a result of uptake by a receptor, followed by partitioning of the compounds into the receptor’s organic carbon compartment-the lipids. Once chemicals are accumulated within an organism’s lipid fraction, biomagnification may occur when organisms at lower trophic levels are preyed upon by receptors higher in the food chain. The net result is an aggregate increase in tissue body burdens of the chemicals at higher trophic levels.

Animals and plants living in or near the River, such as invertebrates, fish, amphibians, and water-dependent reptiles, birds, and mammals, are or can be exposed to PCBs directly and/or indirectly through the food chain. Ecological exposure to PCBs is primarily an issue of bioaccumulation through the food chain rather than direct toxicity, because PCBs bioaccumulate in the environment by bioconcentrating (i.e., being absorbed from water and accumulated in tissue to levels greater than those found in surrounding water) and biomagnifying (i.e., increasing in tissue concentrations as they go up the food chain through two or more trophic levels). As a result, the ecological risk assessment emphasizes indirect exposure at various levels of the food chain to address PCB-related risks at higher trophic levels. The ecological conceptual model is provided in Figure 3.

Assessment Endpoints

Appropriate selection and definition of assessment endpoints, which focus the risk assessment design and analysis, are critical to the utility of risk assessment. It is not practical, nor possible, to directly evaluate risks to all of the individual components of the ecosystem at the Site. Assessment endpoints were selected for the risk assessment based on particular components of the ecosystem that could be adversely affected by the contaminants present. Eight assessment endpoints were developed to evaluate the risk of contaminants in the Lower Fox River and Green Bay. They include the functioning of water column and benthic invertebrate populations, benthic and pelagic fish survival and reproduction, insectivorous, piscivorous, and carnivorous bird survival and reproduction, and piscivorous mammal survival and reproduction. By evaluating and protecting these assessment endpoints, it is assumed that this ecosystem as a whole would also be protected.

Conceptual Model

The biological conceptual model identifies where contaminant interactions with biota can occur, describes the uptake of Site contaminants into the biological system (in this case, the water and sediments of the Lower Fox River and Green Bay), and diagrams key receptor contaminant exposure pathways. Due to the large area being assessed for risk, more than one conceptual model was necessary. The Lower Fox River, from the mouth of Lake Winnebago to the De Pere dam, was evaluated using the same conceptual model (Figure 3).

Measurement Endpoints

Risk questions are assessed using measurement endpoints. Types of measurement endpoints used in the risk assessment process fall generally into four categories: 1) comparison of estimated or measured exposure levels of COPCs to levels known to cause adverse effects, 2) bioassay testing of site and reference media, 3) in-situ toxicity testing of Site and reference media, and 4) comparison of observed effects on-site with those observed at a reference site. Measurement endpoints selected for assessment endpoint evaluation in this risk assessment consistently fell in to the first category of measurement endpoints and are presented in Table 6-2 from BLRA. Only existing data were evaluated as part of this assessment. As such, the measurement endpoints were fashioned around the existing data. Where the data did not already exist to fulfill the measurement endpoint, it was modeled based on the existing data.

**Exposure Assessment**

The exposure assessment includes a quantitative evaluation of contaminant release, migration, and fate; characterization of exposure parameters; and measurement or estimation of exposure point concentrations. Complete exposure pathways and exposure parameters (e.g., body weight, prey ingestion rate, home range) used to calculate the concentrations or dietary doses to which the receptors of concern may be exposed were obtained from EPA references, the scientific literature and directly from researchers. In the FRDB, data were generally lacking for piscivorous and carnivorous birds, and no data were available for piscivorous mammals, therefore, ecological modeling was used to estimate COPC exposure to these receptors.

Description of Groups of Key Species

Invertebrate communities constitute a vast portion of the basis of the food chain in aquatic ecosystems. Since invertebrates process organic material and are prey items for other invertebrates, fish, and birds, they are important in nutrient and energy transfer in an aquatic ecosystem. Alterations in invertebrate functions may consequently affect nutrient and energy transfer, and bird and fish populations. Also, COPCs in invertebrates may be passed along through the food chain. Therefore, upper trophic levels can be affected not only by reduced prey abundance, but also by trophic transfer of accumulated contaminants in invertebrate prey. Examples of important benthic invertebrates in the Lower Fox River system include chironomids (e.g., midges) and oligochaetes (e.g., segmented worms).

Fish have many roles in the aquatic ecosystem, including the transfer of nutrients and energy, and are prey for mammals, birds, and predatory fish. In fact, several predators rely solely, or primarily, on fish for survival. Fish typically constitute a large proportion of the biomass in aquatic systems. Additionally, fish have social and economic value; impaired fish communities would adversely affect commercial and recreational fishing. Benthic fish are those fish that live in contact with and forage for food directly in the sediments. As such, they represent a unique exposure pathway because of their foraging behavior (i.e., high exposure to sediments) and prey items (i.e., predominately benthic invertebrates). Examples of benthic fish in the Lower Fox River include carp, catfish, and bullhead. Pelagial fish are those species that live and feed principally in the water column (as opposed to being in direct contact with sediment). Pelagial fish represent many trophic levels with prey items predominately in the water column (e.g., zooplankton and other fish). Examples of important pelagial fish in the Lower Fox River include shiners, shad, alewife, perch, and walleye. Pelagial fish important to Green Bay include the same species as are found in the River, in addition to lake trout and other salmonids in the upper Bay.

Bird populations, in general, present one of the most significant biological components of the River/Bay system and occupy several trophic levels. Given the potential for some contaminants to biomagnify, birds, as upper trophic level receptors, may concentrate, and be affected by, contaminants in their tissues to a greater degree than lower trophic level species. In addition to their ecological importance, birds are socially valued because of recreational activities and aquatic aesthetics. Insectivorous birds rely predominately on insects (e.g., benthic invertebrates) for food. Examples of insectivorous birds in the Lower Fox River and Green Bay region include swallows and blackbirds. Piscivorous birds rely primarily on fish for food. Of the bird populations present at the Site, piscivorous birds represent a high trophic level and, therefore, are more at risk than insectivores from contaminants transferred through the food chain. Examples of piscivorous birds on the Lower Fox River and Green Bay include cormorants and terns. Carnivorous birds were selected for evaluation because of their diverse forage, which can include consumption of fish, piscivorous birds, or even small mammals. Examples of carnivorous birds on the Lower Fox River and Green Bay include eagles, osprey, and other raptors.

Piscivorous mammals represent the upper trophic level of the riverine corridor ecosystem and, therefore, are potentially highly exposed to contaminants that bioaccumulate or biomagnify. Piscivorous mammals rely primarily on fish as food, but may also consume amphibians, invertebrates, crayfish, clams, and mussels. The foraging behavior of these mammals represents a pathway through which energy is transferred from the aquatic to terrestrial ecosystem. Mink are piscivorous mammals found in the Lower Fox River and Green Bay area.

A number of different animals have been or are currently on the Wisconsin, Michigan, or Federal Endangered and Threatened Species lists. Listed animals which have historically been found in the vicinity of the Lower Fox River or Green Bay include: osprey, common tern, Forsters tern, Caspian tern, and great egret (Matteson *et al*., 1998). The osprey, common tern, and Forsters tern have nested along the Lower Fox River as well as at upstream locations in Lake Winnebago, Little Lake Butte des Morts, and Lake Poygan. Osprey have been sighted near Kaukauna and have attempted to nest in the vicinity of Combined locks, while terns have been observed farther upstream. Additionally, Caspian tern and great egret have nested on some of the islands located in Green Bay. Very few nesting pairs have been observed over the past few years and recovery of these populations is slow (Matteson *et al.*, 1998).

In addition to these birds, the WDNR reported a bed of clams or mussels, which may be threatened. The sediment bed, which these clams/mussels inhabit, is approximately 6 meters (20 feet) wide and 30.5 meters (100 feet) long and is located near the mouth of Mud Creek in the Lower Fox River (Szymanski, 1998, 2000).

As mentioned above, populations of both eagles and the double crested cormorants have recovered to the point where both birds have been removed from the Wisconsin endangered species list. Other populations, specifically, wild mink and otter, have been found to be declining around the Lower Fox River and Green Bay, yet they are not currently listed by state or federal agencies. The endangered and threatened fish and birds of the region were listed on Tables 2-11 and 2-12 of the BLRA. The endangered and threatened mammals of the region are listed in Table 2-14 of the BLRA.

**Derivation of Exposure Point Concentrations**

<u>All COPCs</u>
Tables 9 through 13 show the exposure point concentrations for chemicals where risk was indicated. For calculation of exposure values, one-half of the sample quantitation limit was used for undetected values (EPA, 1991b). The 95 percent UCL of the mean is the value that a mean, calculated repeatedly from subsamples of the data population, will not exceed 95 percent of the time. Therefore, there is a 95 percent probability that the true mean of the population does not exceed the 95 percent UCL. The 95 percent UCL was calculated from the sample values depending on whether the data were normally, log-normally, or not normally distributed. When the data distribution fit neither a normal nor log-normal distribution pattern, the 95 percent UCL selected was the greater of the two calculated 95 percent UCLs (normal and log-normal). In cases where data was limited, or where the variability in the data was high, the calculated 95 percent UCL can exceed the maximum detected concentration. The RME is defined as the lesser of the calculated 95 percent UCL, or the maximum detected value.

As an estimate of risk, both the arithmetic mean concentration and the RME concentration are used as exposure point concentrations. The RME is an estimate of the highest average exposure expected to occur at a Site. The intent of the RME is to provide an estimate of exposure that is above average, yet still within the range of most exposures. The RME thus provides a degree of protectiveness that encompasses the individual receptors that have a higher likelihood of exposure.

**Table 9 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Water Column Invertebrates**

| | |
|---|---|
| **Scenario Time Frame:** | **Current** |
| **Medium:** | **Water** |
| **Exposure Medium:** | **Surface water** |

| Exposure Point | Chemical of Concern | Concentration Detected (ng/l) | | Frequency of Detection | Exposure Point Concentration (ng/l) | Statistical Measure |
|---|---|---|---|---|---|---|
| | | Min. | Max. | | | |
| Surface Water (OU 1) | Mercury (unfiltered) | 0.2 | 7140 | 5/6 | 7140 | max |
| | | | | | 2237 | mean |
| | Total PCBs (filtered) | 1.4 | 19 | 40/46 | 15.3 | 95% UCL |
| | | | | | 11.1 | mean |
| | Total PCBs (unfiltered) | na | na | 0/6 | | |
| | Total PCBs (particulates) | 0.1 | 40.2 | 34/41 | 40.2 | max |
| Surface water (OU 2) | Total PCBs (particulate) | 0.01 | 52.2 | 82/86 | 52.2 | max |
| | | | | | 11.9 | mean |
| | | | | | 16.6 | mean |

*na = not applicable*

**Table 10 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Benthic Invertebrates**

| | |
|---|---|
| **Scenario Time Frame:** | **Current** |
| **Medium:** | **Sediment** |
| **Exposure Medium:** | **Sediment** |

| Exposure Point | Chemical of Concern | Concentration Detected | | Frequency of Detection | Exposure Point Concentration | Statistical Measure |
|---|---|---|---|---|---|---|
| | | Min | Max | | | |
| Sediments (OU 1) | Lead (mg/kg) | 3.8 | 522 | 27/27 | 172 | mean |
| | | | | | 522 | max |
| | Mercury (mg/kg) | 0.2 | 3.3 | 71/86 | 1.4 | 95 %UCL |
| | | | | | 1 | mean |
| | 2,3,7,8-TCDD (µg/kg) | 1.80e-03 | 5.40e-03 | 4/5 | 4.30e-03 | 95% UCL |
| | | | | | 2.50e-03 | mean |
| | Total PCBs (µg/kg) | 25 | 130,000 | | 22,848 | 95% UCL |
| | | | | | 10,724 | mean |
| | DDD (µg/kg) | 4.7 | 19 | 4/23 | 19 | max |
| | | | | | 17.8 | mean |
| | DDT (µg/kg) | 13 | 50 | 2/20 | 50 | max |
| Sediments (OU 2) | Lead (mg/kg) | 44 | 130 | 10/10 | 88.9 | 95% UCL |
| | | | | | 75.6 | mean |
| | Mercury (mg/kg) | 0.2 | 2.1 | 10/10 | 1.7 | 95% UCL |
| | | | | | 0.8 | mean |
| | Total PCBs (µg/kg) | 3.50e +01 | 7.42e+04 | 122/131 | 1.53e+04 | 95% UCL |
| | | | | | 6.75e+03 | mean |

**Table 11 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Fish**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Scenario Time Frame:** | **Current** | | | | | |
| **Medium:** | **Fish** | | | | | |
| **Exposure Medium:** | **Fish** | | | | | |
| **Exposure Point** | **Chemical of Concern** | **Concentration Detected** | | **Frequency of Detection** | **Exposure Point Concentration** | **Statistical Measure** |
| | | **Min** | **Max** | | | |
| OU 1 | | | | | | |
| whole fish tissue (carp) | PCBs (µg/kg) | 245 | 11,400 | 30/30 | 2957 | 95% UCL |
| | | | | | 1992 | mean |
| whole fish tissue (gizzard shad) | PCBs (µg/kg) | 54 | 530 | 4/4 | 530 | max |
| | | | | | 296 | mean |
| whole fish tissue (golden shiner) | PCBs (µg/kg) | 845 | 1140 | 2/2 | 1140 | max |
| | | | | | 993 | mean |
| whole fish tissue (yellow perch) | PCBs (µg/kg) | 363 | na | 1/1 | 363 | max |
| whole fish tissue (walleye) | PCBs (µg/kg) | 98.9 | 3800 | 11/13 | 3800 | max |
| | | | | | 1159 | mean |
| OU 2 | | | | | | |
| whole fish tissue (carp) | PCBs (µg/kg) | 160 | 6600 | 12/12 | 3606 | 95% UCL |
| | | | | | 2581 | mean |
| whole fish tissue (yellow perch) | PCBs (µg/kg) | 425 | 1298 | 4/4 | 1219 | 95% UCL |
| | | | | | 779 | mean |
| whole fish tissue (walleye) | PCBs (µg/kg) | 1431 | 3900 | 4/4 | 3900 | max |
| | | | | | 2737 | mean |
| *na = not applicable* | | | | | | |

**Table 12 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Birds**

| | |
|---|---|
| **Scenario Time Frame:** | **Current** |
| **Medium:** | **Prey Items** |
| **Exposure Medium:** | **Prey Items** |

| Exposure Point | Chemical of Concern | Concentration Detected | | Frequency of Detection | Exposure Point Concentration | Statistical Measure |
|---|---|---|---|---|---|---|
| | | Min | Max | | | |
| OU 1 | | | | | | |
| Tree swallow egg | PCBs (µg/kg) | 1790 | 4030 | 5/5 | 3732 | 95% UCL |
| | | | | | 2924 | mean |
| Tree swallow whole body | PCBs (µg/kg) | 79 | 7400 | 24/24 | 5254 | 95% UCL |
| | | | | | 2135 | mean |
| Common tern ingestion | mercury (µg/kg) | na | na | na | 1.5 | mean |
| | | | | | 1.6 | RME |
| | mercury (µg/kg -BW/day) | na | na | na | 12.5 | mean |
| | | | | | 13.1 | RME |
| | total PCBs (µg/day) | na | na | na | 17.4 | mean |
| | | | | | 31.2 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 145 | mean |
| | | | | | 260 | RME |
| Forster's tern ingestion | mercury (µg/kg) | na | na | na | 1.8 | mean |
| | | | | | 1.9 | RME |
| | mercury (µg/kg-BW/day) | na | na | na | 11.5 | mean |
| | | | | | 12.1 | RME |
| | total PCBs (µg/kg) | na | na | na | 21.2 | mean |
| | | | | | 37.9 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 134 | mean |
| | | | | | 240 | RME |
| Double Crested Cormorant ingestion | mercury (µg/kg) | na | na | na | 8.1 | mean |
| | | | | | 8.6 | RME |

**Table 12 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Birds**

| | |
|---|---|
| **Scenario Time Frame:** | **Current** |
| **Medium:** | **Prey Items** |
| **Exposure Medium:** | **Prey Items** |

| Exposure Point | Chemical of Concern | Concentration Detected | | Frequency of Detection | Exposure Point Concentration | Statistical Measure |
|---|---|---|---|---|---|---|
| | | Min | Max | | | |
| | mercury (µg/kg-BW/day) | na | na | na | 4.8 | mean |
| | | | | | 5.1 | RME |
| | total PCBs (µg/kg) | na | na | na | 94.1 | mean |
| | | | | | 168 | RME |
| | total PCBs (µg/kg-BW) | na | na | na | 56 | mean |
| | | | | | 100 | RME |
| bald eagle | total PCBs (µg/kg) | na | na | na | 963 | mean |
| | | | | | 1647 | RME |
| | total PCBs (µg/kg-BW) | na | na | na | 207 | mean |
| | | | | | 354 | RME |
| OU 2 | | | | | | |
| common tern ingestion | mercury (µg/kg) | na | na | na | 1.5 | mean |
| | | | | | 1.5 | RME |
| | mercury (µg/kg-BW/day) | na | na | na | 12.3 | mean |
| | | | | | 12.3 | RME |
| | total PCBs (µg/kg) | na | na | na | 45.8 | mean |
| | | | | | 71.6 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 382 | mean |
| | | | | | 597 | RME |
| Forster's tern ingestion | mercury (µg/kg) | na | na | na | 1.8 | mean |
| | | | | | 1.8 | RME |
| | mercury (µg/kg-BW/day) | na | na | na | 11.3 | mean |
| | | | | | 11.3 | RME |
| | total PCBs (µg/kg) | na | na | na | 55.6 | mean |
| | | | | | 87 | RME |

**Table 12 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Birds**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Scenario Time Frame:** | **Current** | | | | | |
| **Medium:** | **Prey Items** | | | | | |
| **Exposure Medium:** | **Prey Items** | | | | | |
| **Exposure Point** | **Chemical of Concern** | **Concentration Detected** | | **Frequency of Detection** | **Exposure Point Concentration** | **Statistical Measure** |
| | | **Min** | **Max** | | | |
| | total PCBs (µg/kg-BW/day) | na | na | na | 352 | mean |
| | | | | | 551 | RME |
| double crested cormorant | mercury (µg/kg) | na | na | na | 8 | mean |
| | | | | | 8 | RME |
| | mercury (µg/kg-BW/day) | na | na | na | 4.7 | mean |
| | | | | | 4.7 | RME |
| | total PCBs (µg/kg) | na | na | na | 249 | mean |
| | | | | | 388 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 148 | mean |
| | | | | | 231 | RME |
| bald eagle ingestion | mercury (µg/kg) | na | na | na | 40 | mean |
| | | | | | 67.4 | RME |
| | mercury (µg/kg-BW/day) | na | na | na | 8.6 | mean |
| | | | | | 14.5 | RME |
| | total PCBs (µg/kg) | na | na | na | 1376 | mean |
| | | | | | 1930 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 296 | mean |
| | | | | | 415 | RME |
| bald eagle egg | total PCBs (µg/kg) | na | 36000 | 1/1 | 36000 | max |

na = not applicable

RME = reasonable maximum exposure

BW = body weight

**Table 13 Summary of Chemicals of Concern and Medium-Specific Exposure Point Concentrations for Mammals**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Scenario Time Frame:** | **Current** | | | | | |
| **Medium:** | **Prey items** | | | | | |
| **Exposure Medium:** | **Prey items** | | | | | |
| **Exposure Point** | **Chemical of Concern** | **Concentration Detected** | | **Frequency of Detection** | **Exposure Point Concentration** | **Statistical Measure** |
| | | **Min** | **Max** | | | |
| Mammal ingestion (OU 1) | total PCBs (µg/day) | na | na | na | 348 | mean |
| | | | | | 544 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 435 | mean |
| | | | | | 680 | RME |
| Mammal ingestion (OU 2) | total PCBs (µg/day) | na | na | na | 422 | mean |
| | | | | | 613 | RME |
| | total PCBs (µg/kg-BW/day) | na | na | na | 527 | mean |
| | | | | | 766 | RME |

*na = not applicable*

*RME = reasonable maximum exposure*

*BW = body weight*

**PCB-Specific Exposure Point Concentrations**

Water

Filtered and particulate concentrations of PCBs were detected in all River reaches and Green Bay zones and these concentrations were summed to estimated total water concentrations of total PCBs. Estimated mean, 95 percent UCL, and maximum total PCB concentrations in water are presented on Figure 6-6 of the BLRA. Estimated mean total PCB concentrations were greatest in Green Bay Zone 1 (60.9 µg/L) and represented an increase of 2.2 times over the estimated mean total PCB concentrations in Little Lake Butte des Morts (27.6 µg/L).

Sediment

Total PCBs were detected frequently in all River reaches and Green Bay zones. Measured concentrations are reported in three different ways: non-interpolated, interpolated ($I_0$), and interpolated ($I_d$) for all of the River reaches, but, as discussed in Section 6.4.1 of the BLRA, $I_0$ concentrations are not presented for zones 2, 3A, 3B, or 4 of Green Bay. In contrast to metals, PCB concentrations generally decreased moving down the River and into the Bay. The mean total PCB concentration ranged from 82.9 µg/kg (Green Bay Zone 4) to 10,724 µg/kg (Little Lake Butte des Morts). Mean, 95 percent UCL, and maximum concentrations of PCBs are presented on Figure 6-8 of the BLRA.

Fish

Total PCBs were detected frequently in all River reaches and Green Bay zones. The range of detection frequency was 85 to 100 percent. The mean total PCB concentration ranged from 79.8 µg/kg (yellow perch from Green Bay Zone 4) to 6,637 µg/kg (carp from Green Bay zones 1 and 2). Mean, 95 percent UCL, and maximum total PCB concentrations in yellow perch, carp, and walleye are presented on Figure 6-11 of the BLRA. Mean, 95 percent UCL, and maximum total PCB concentrations in forage fish species (gizzard shad, alewife, shiner species, and rainbow smelt) are presented on Figure 6-12 of the BLRA.

Birds

Where they were analyzed, total PCBs were detected at a frequency of 100 percent, except for Green Bay Zone 3B where they were detected at a frequency of 95 percent. The mean total PCB concentration ranged from 2,135 µg/kg (whole tree swallow from Little Lake Butte des Morts) to 11,026 µg/kg (whole double-crested cormorants from Green Bay Zone 2). Measured total PCB concentrations in birds are presented on Figure 6-15 of the BLRA. As indicated by this figure, the area where the most bird species were sampled was Green Bay Zone 2. This area also contained the highest concentrations of total PCBs, found in double-crested cormorants.

Mammals

LLBdM: The mean estimated exposure concentration for total PCBs (N), total PCBs ($I_0$), and total PCBs ($I_d$) were 435, 397, and 400 µg/kg-BW/day, respectively.
Appleton-LR: The mean estimated exposure concentration for total PCBs (N), total PCBs ($I_0$), and total PCBs ($I_d$) were 527, 494, and 501 µg/kg-BW/day, respectively.

Summary of Field Studies

Within the Lower Fox River and Green Bay system, there have been numerous field studies on a variety of different species. Many of the species studied were also evaluated in the BLRA as receptor species that represented the assessment endpoints in the BLRA. While not specifically included in the risk characterization, the studies are presented in BLRA Section 6.5.4 to provide the risk managers with an integrated tool for decision-making.

## Effects Assessment

Toxic effects of all COPCs were evaluated in the BLERA. Section 6.3 of the BLRA provides details of the effects of all the COPCs on the assessment endpoints. The rest of the discussion below focuses on effects of PCBs only.

PCBs have been shown to cause lethal and sub-lethal reproductive, developmental, immunological and biochemical effects. The risk assessment limited its focus to adverse impacts on survival, growth and reproduction. The ecological effects assessment includes literature reviews, field studies and toxicity tests that correlate concentrations of PCBs to effects on ecological receptors. Toxic equivalency factors, based on the toxicity of dioxin, have been developed for the dioxin-like PCB congeners. The effects of PCBs on Great Lakes fish and wildlife have been extensively documented. PCB-induced reproductive impairment has been demonstrated for several fish species (Mac, 1988; Ankley *et al.*, 1991; Walker and Peterson, 1991; Walker *et al*., 1991a, 1991b; Williams and Giesy, 1992), a number of insectivorous and piscivorous birds (Kubiak *et al.*, 1989; Gilbertson *et al.*, 1991; Tillitt *et al.*, 1992) and mink (Aulerich *et al.*, 1973, Aulerich and Ringer, 1977; Bleavins *et al.*, 1980; Wren, 1991; Giesy *et al.*, 1994c; Heaton *et al.*, 1995a, 1995b; Tillitt *et al.*, 1996).

### Derivation of TRVs

In order to derive toxicity reference values (TRVs), a comprehensive literature search was performed for all COPCs. A variety of databases were searched for literature references containing toxicological information. Some of these literature sources included Biological Abstracts, Applied Ecology Abstracts, Chemical Abstract Services, Medline, Toxline, BIOSIS, ENVIROLINE, Current Contents, Integrated Risk Information System (IRIS), the Aquatic Information Retrieval Database (AQUIRE) maintained by the EPA, and the Environmental Residue Effects Database (ERED) maintained by the EPA and U.S. Army Corps of Engineers. The TRVs selected for this assessment were discussed with and agreed upon by BTAG members. Importantly, the consensus on the TRVs are for site-specific use only and are not intended to be used at other sites (Table 6-5 of the BLRA).

TRVs were used to estimate the potential for ecological risk at the Site. The selected TRVs were either Lowest Observed Adverse Effects Levels (LOAELs) and/or No Observed Adverse Effects Levels (NOAELs) from laboratory and/or field based studies reported in the scientific literature. LOAELs are the lowest values at which adverse effects have been observed, and NOAELs are the highest values at which adverse effects were not observed.

The PCB and dioxin-like PCB congener TRVs for fish, birds and mammals are based on effects on survival, growth, and reproduction of fish and wildlife species in the Fox River. Reproductive effects (e.g., egg maturation, egg hatchability and survival of juveniles) were generally the most sensitive endpoints for animals exposed to PCBs.

### Risk Characterization

<u>Hazard Quotient Calculations</u>
Risk characterization for each assessment endpoint was based upon the calculated HQs and, as available, population or field study data. Hazard quotients calculated based on literature values, provide one line of evidence for characterizing ecological effects. Field studies were evaluated, where appropriate, as a supplement to the risk evaluation, particularly when the contamination has a historical basis (EPA, 1994b, 1997a).

While HQs and other lines of evidence (i.e., field studies and other data types) cannot be quantitatively combined, each can inform risk managers on the presence of risk and how these risks may be reduced. Therefore, this risk characterization process did not result in the distillation of a single conclusive statement regarding overall risk to each assessment endpoint. Consideration of the magnitude of uncertainty, discussed in Section 6.6 of the BLRA, is also a key component of the risk interpretation process.

For this risk assessment it was agreed by BTAG that degree of risk would be determined based on three categories: "no" risk was concluded when both the NOAEC and LOAEC HQs evaluated were less than 1.0, "potential" risk was concluded when the NOAEC HQ exceeded 1.0 but the LOAEC HQ was less than 1.0, and risk ("yes") was concluded when both the NOAEC and LOAEC HQs evaluated were greater than 1.0. When constituents were analyzed but not detected, it was concluded that no risk existed.

**OU 1 - Little Lake Butte des Morts Summary**. In summary, the results suggest that only measured or estimated concentrations of total PCBs are at sufficient levels to cause risk to benthic invertebrates, and piscivorous mammals. Potential risks from total PCBs are indicated for water column invertebrates, benthic and pelagic fish, and insectivorous, piscivorous, and carnivorous birds. Measured or estimated concentrations of mercury are found to be at sufficient concentrations to cause or potentially cause risk to water column and benthic invertebrates, and piscivorous birds. Concentrations of 2,3,7,8-TCDD, DDD, and DDT are only sufficient to be of risk to benthic invertebrates. Sediment concentrations of elevated PCBs are widespread and persistent throughout the reach. Concentrations of arsenic, dieldrin, and all o,p'- isomers of DDT and its metabolites are not found to pose risk to any assessment endpoint.

**OU 2 - Appleton to Little Rapids Summary.** In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause risk to benthic invertebrates, carnivorous birds, and piscivorous mammals. Potential risks are indicated for all other receptors except insectivorous birds, for which there are no data. Measured or estimated concentrations of mercury were found to be at sufficient concentrations to cause risk to benthic invertebrates, piscivorous birds, and carnivorous birds. Concentrations of lead are only of risk to benthic invertebrates. Concentrations of all chlorinated pesticides are not found to pose risk to any assessment endpoint. Surface sediment concentrations of elevated PCBs indicate reach-wide effects, but are likely limited to specific deposits.

Major Findings

A summary of the risk to each assessment endpoint in each reach and zone is presented in Table 6-134 of the BLRA. OU 1 and OU 2 are discussed below and summarized in Table 14. Risk assessment summaries will be provided for OU 3, OU 4 and OU 5 in subsequent RODs.

The principle findings of the ecological risk assessment are:

- Total PCBs cause, or potentially cause risk to all identified receptors. The exception is insectivorous birds where the weight of evidence suggests that these receptors are not at risk from PCB concentrations. Not all receptors at risk or potentially at risk from PCBs are at risk in all River reaches or Bay zones.
- Mercury poses a risk in all River reaches and zones, but not to all receptors. Mercury was not identified as a risk for benthic fish, insectivorous birds, or piscivorous mammals.
- DDT or its metabolites poses a risk to benthic invertebrates in OU 1 (i.e., Little Lake Butte des Morts Reach).

**Table 14 Ecological Risk Summary**

| OU | Water Column Invertebrates | | Benthic Invertebrates | | Benthic Fish | | Pelagic Fish | | Insectivorous Bird | | Piscivorous Bird | | Carnivorous Bird | | Piscivorous Mammal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ● ☼ | Mercury PCBs | ● | PCBs, lead, mercury, DDD,DDT, 2,3,7,8TCDD | ☼ | PCBs | ☼ | PCBs | ☼ | PCBs | ☼ | mercury, PCBs | ☼ | PCBs | ● | PCBs |
| 2 | ☼ | PCBs | ● | lead, mercury, PCBs | ☼ | PCBs | ☼ | PCBs | | NA | ☼ | mercury, PCBs | ● ☼ | PCBs, mercury | ● | PCBs |

**Notes:**

NA = no data available

**Risk conclusions based on HQs**

= No risk

● = Risk

☼ = Potential Risk

**Risk Conclusions based on weight of evidence**

= Site specific receptor data suggest that there is no risk

= Because of the Federal listing of the bald eagle as threatened, it is concluded that potential risk is actual risk

Uncertainty

The goal of this uncertainty analysis is to both qualitatively, and quantitatively to the degree possible, define the degree of confidence that exists with the estimations of effects from exposure to hazardous chemicals in toxic amounts. Bounding the certainty of risk estimates is a developing science. EPA's Superfund Ecological Risk Assessment Guidance (EPA, 1997a) and the Guidelines for Ecological Risk Assessment (EPA, 1998b) provide general instructions on what should be addressed in an uncertainty analysis.

Conceptual Site Model

Qualitatively, there is a high degree of certainty that factors (such as fate and distribution, downstream transport, biological uptake, effects on field populations, habitat and life histories of important fish, birds, and mammals within the River and Bay) are well understood and adequately characterized in the conceptual site model. There remains, however, some uncertainty as to whether the receptors identified within the conceptual site model adequately represent the ecosystem and other species potentially at risk within the Lower Fox River. The selection of the important receptor species was done in consultation with biologists both within the WDNR and the USFWS. In addition, input on the receptor species was given by biologists and resource managers within EPA, NOAA, and the Oneida and Menominee Nations through the USEPA Biological and Technical Assistance Group (BTAG) process. However, despite this, there remains a class of organisms and a threatened species that was not addressed in this BLRA. Reptile and amphibian species were not evaluated for risk because there are no data within the FRDB to evaluate this receptor group, and there are no uptake models to estimate risk for frogs or other amphibians. For the fish species sturgeon, listed as a threatened species in Michigan, but not in Wisconsin, there are also too few data points within the FRDB to evaluate potential risks.

Data

The FRDB represents numerous separate data collection efforts with over 500,000 discrete data records of air, water, sediments, and tissue, from throughout the Lower Fox River and Green Bay. A rigorous evaluation of the quality of the data was undertaken, and only data for which at least partial QA packages could be reviewed were placed into the FRDB. Of the studies between 1971 and 1991, only partial packages could be reviewed, and so those data were used as supporting evidence within the BLRA. There have been several studies completed on the Fox River in the 1990s. All studies conducted after 1992 have fully validated data packages. Given the temporal and spatial density of the data within the Lower Fox River, there are good reasons to assume that the overall quality of the data is high, and thus the related degree of data uncertainty is low. There were no significant biases or gaps observed within the sediment, fish, or bird sample data.

Another data gap within the BLRA is that there are limited measurements of metals and the organochlorine pesticides in the surface water. However, this impacts only the ability to assess risks to pelagic invertebrate communities, and the remaining assessment endpoints could be addressed through the other media (e.g., bird tissues) for which data were judged adequate. Finally, there are relatively too few data on all PCB congeners for all media within the Lower Fox River and Green Bay to make conclusive assessments or predictions of risk. While the FRDB contains numerous congener-specific data points, until relatively recently all of the dioxin-like congeners have not been adequately assessed. For example, while PCB congener 169 has been detected in the fish and birds of the River and Bay, there have been too few measurements taken in sediments or water.

Temporal

A time trends analysis was undertaken to specifically address the question of losses or gains in PCB concentrations over time in sediments and fish. For sediments, a large fraction of analyses provided little useful information for projecting future trends because of the lack of statistical significance and the wide confidence limits observed. This is especially true for sediments below the top 4 inches; changes in the sediment PCB concentrations cannot be distinguished from zero-or no change. Generally over time, however, the surface sediment concentrations (i.e., top 10 cm) of PCBs have been steadily decreasing, but the rate of change in surface sediments is both reach- and deposit-specific. The change averages an annual decrease of 15 percent, but ranges from an increase of 17 percent to a decrease of 43 percent. Given these conditions, the sediment data used may over- or under-evaluate the risks dependent upon how much older data were used in the point estimates or interpolated bed maps.

Like sediment PCB concentrations, fish tissue PCB concentrations showed a significant but slow rate of change throughout the Lower Fox River and Green Bay. In all of the reaches of the River and in Zone 2, there were steep declines in fish tissue PCB concentrations from the 1970s, but with significant breakpoints in declines beginning around 1980. After the breakpoint, depending upon the fish species, the additional apparent declines were either not significantly different from zero, or were relatively low (i.e., 5 to 7 percent annually). In addition, there are some increases in fish tissue PCB concentrations. Walleye in Little Lake Butte des Morts show a non-significant increase of 22 percent per year since 1987. Likewise, gizzard shad in Zone 2 show a non-significant increase of 6 percent per year into 1999. These data, taken collectively, suggest that since the breakpoint for tissue declines occurred in the early 1980s and the changes in fish tissue concentrations were no greater than 4 to 7 percent annually, aggregating fish tissue from 1989 does not likely result in any significant biasing of the risk estimations. At worst, the tissue point estimates might overestimate risks by 50 percent (i.e., average of 5 percent per year over 10 years), but given that at least some fish tissue concentrations increased, it is reasonable to suggest that some risks were underestimated by at least an equivalent amount.

Spatial Variability

Uncertainty in the spatial variability refers principally to where sediment samples were collected from within the Lower Fox River and Green Bay. Within the River, most sampling efforts are concentrated in areas where there were thick sediment deposits (e.g., A, POG, N, GG/HH, and the SMUs below De Pere). There were no systematic sampling efforts to define PCB concentrations throughout the River. Within the Bay, systematic grid sampling was employed, but the spatial uncertainty is higher because of the large distance between sampling points. Sediment concentrations used in the risk assessment were based on both non-interpolated and interpolated concentration estimation methods so that the differences in risk estimates could be compared. The calculations demonstrate that in general, using the interpolated sediment yields a lower estimation of sediment-based risk than use of the non-interpolated data.

Toxic Exposure

Point estimates of exposure concentrations were compared in the BLRA to point estimates of toxicity in the literature to yield the hazard quotients. While the rationale used to select the most representative value from the literature was presented in Section 6.3, there remain uncertainties associated with effects concentrations above or below the selected TRV, selection of TRVs from one species and applying to another, interpretation between NOAECs and LOAECs based on application of uncertainty factors, or application of different sets of toxicity equivalent factors from the literature. For PCBs, risk estimation uncertainty was reduced by determining risk potential on a total PCB basis and a PCB congener basis for receptors where both exposure and effects data were available (i.e., fish and birds).

Alternative Exposure Points

The principle exposure point concentration used for risk evaluation in the BLRA was the RME (i.e., the lower of either the 95 percent UCL or the maximum concentration) for all media and receptors evaluated. In order to determine the degree to which risk may have been under or overestimated, 90th percentile concentrations were estimated and evaluated for risk for two representative species; walleye and double crested cormorants.

For walleye, results of this comparison indicated that risk evaluation of the 90th percentile concentrations would result in only two changes to the risk conclusions. Hazard quotients for the total PCB NOAEL for walleye in Green Bay Zone 1 increase from 10 to 14 using the 90th percentile. The risk determination for walleye from total PCBs would change from “potential risk” to “likely risk” in Green Bay zones 1 and 2, and risk from mercury in Green Bay Zone 4 would change from “no risk” to “potential risk”. The net conclusions of the ecological risk assessment for piscivorous fish would be negligibly affected by using the 90th percentile.

For double-crested cormorants, risk evaluation of the 90th percentile concentrations would result in only one change to the risk conclusions. Risk to double-crested cormorants from p,p'-DDE would change from “potential risk” to “likely risk” in Green Bay Zone 3B. Because of the limited 90th percentile data in fish appropriate as prey for double-crested cormorants, dietary concentrations could not be modeled. However, use of the 90th percentile would not appreciably affect the risk determinations for piscivorous birds.

Population Data

As noted previously, while population level endpoints can be an appropriate tool to assess risk, the population data discussed in the BLRA were not collected specifically for risk assessment. There is some uncertainty introduced given the potential for other confounding environmental factors that may affect the absence or abundance of receptors within the Lower Fox River and Green Bay. These can include such things as immigration, emigration, food availability, habitat suitability and availability, species competition, predation, and weather. For example, while the risk assessment concludes that PCBs are at sufficient concentrations to affect mink reproduction within the River and Bay, Section 2 documented that there is limited habitat for mink, especially along the River. While contaminant conditions exist that potentially would jeopardize mink health along the River corridor, the absence of mink due to absence of habitat must be considered.

Likewise, the apparent increase in populations of walleye and cormorants suggest little or no current risks to these species. Increases in walleye populations have occurred since the 1980s, and are directly linked to improvement in water quality and habitat in the Lower Fox River, and not necessarily to decreases in contaminants. Evidence that some risks persist is evidenced in the apparent presence of pre-cancerous lesions. Cormorant population increases may be related to decreases in contaminant concentrations, but are also likely tied to increases in available prey (fish). Like walleye, sublethal conditions appear to persist within the cormorant population. Given a shift in food or habitat conditions, those risks could be potentially of greater concern.

Quantitative Analysis
Only the data for benthic infauna for the Lower Fox River were thought to be amenable to a quantitative analysis. This analysis involved *using* of a range of toxicity values as listed in the literature rather than the single point estimate for toxicity that was used in the main body of the BLRA. This re-analysis was done for each River reach and Green Bay zone.

- LLBdM: There is a high probability (70 to 80 percent) that PCBs are widely distributed throughout the reach at sufficiently high concentrations to moderately effect benthic infaunal populations, and at least a 40 to 50 percent probability of encountering PCB concentrations associated with extreme effects.
- Appleton-LR: For this reach, the probability of infaunal organisms encountering levels of PCBs associated with toxic effects is low (5 to 10 percent).

Concluding Statement
The evaluation of uncertainties did not change the general conclusions drawn from the BLRA, which are that:

- Fish consumption by other fish, birds and mammals is the exposure pathway that represents the greatest level of risk for receptors (other than direct risk to benthic invertebrates).

The primary COC is PCBs, and other COCs carried forward for remedial evaluation and long-term monitoring are mercury and DDE.

## 8.4 Derivation of SQTs

Sediment Quality Thresholds (SQTs) are sediment concentrations that have been linked to a specific magnitude of risk. SQTs were developed for each pathway and receptor identified as important in the BLRA by the response agencies of the Lower Fox River and Green Bay (e.g., sport fishing consumption, bald eagles). The SQTs themselves are not cleanup criteria, but were used to evaluate levels of PCBs in the Feasibility Study. The final selection of the remedial action levels is a policy decision left to the response agencies.

SQTs were estimated for PCBs with the assumption that a remedy that reduces PCB exposure would also address the other co-located COCs. Risk-based concentrations in fish for human and ecological receptors were determined based on:

- Human health cancer risk levels of $10^{-4}$, $10^{-5}$, and $10^{-6}$, and a noncancer hazard index of 1.0 for risk in recreational anglers and high-intake fish consumers
- The NOAECs and LOAECs for species of benthic invertebrates, fish, birds, and riverine mammals found in the River and Bay.

### 8.5 Basis for Action

The excess cancer risk and non-cancer health hazards associated with human ingestion of fish, as well as the ecological risks associated with ingestion of fish by birds, fish and mammals, are above acceptable levels under baseline conditions. The response action selected in this ROD is necessary to protect the public health or welfare and the environment from actual releases of hazardous substances into the environment.

## 9. REMEDIAL ACTION OBJECTIVES

Consistent with the NCP and RI/FS Guidance, WDNR and EPA developed remedial action objectives (RAOs) for the protection of human health and the environment. The RAOs specify the contaminants and media of concern, exposure routes and potential receptors, and an acceptable concentration limit or range for each contaminant for each of the various media, exposure routes and receptors. RAOs were then used to establish specific Remedial Action Levels (RAL) for the Site. Action Levels were established after review of both the preliminary chemical-specific ARARs and risk-based concentrations and serve to focus the development of alternatives or remedial technologies that can achieve the remedial goals. Although this ROD only addresses remediation of OUs 1 and 2, the RAOs were developed for the entire Lower Fox River and Green Bay and are therefore discussed here. Additional activities as they relate to these RAOs for OUs 3 through 5 will be discussed in a subsequent ROD or RODs.

The FS brought together the four major components used to evaluate risk, remedial goals, and alternative technologies in its analysis of remedial options. These components are briefly described below, then discussed in more detail on the following pages.

- **Remedial Action Objectives.** RAOs are site-specific goals for the protection of human and ecological health. Five RAOs were developed; all five apply to the River, while RAOs 1, 2, 3, and 5 apply to Green Bay.
- **Remedial Action Levels.** A range of action levels were considered for the River and Bay; action levels were chosen based in part on Sediment Quality Thresholds (SQTs), which link risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. The SQTs were developed in the human health and ecological risk assessments.
- **Operable Units.** The four reaches (OU 1 through OU 4) and Green Bay (OU 5) were identified based on geographical similarities for the purpose of analyzing remedial actions.
- **Remedial Alternatives.** Following a screening process detailed in the FS, six remedial alternatives (A-F) were retained for the Lower Fox River and seven (A-G) were retained for Green Bay.

For each River reach, six possible remedial alternatives were applied to each of five possible action levels and evaluated against each of five remedial action objectives. For each Green Bay zone, seven possible remedial alternatives were applied to each of three possible action levels and evaluated against each of four remedial action objectives. The steps in this process are described in more detail below. Cost estimates were also prepared for each combination of River reach/Bay zone, remedial alternative, and action level.

### 9.1 Remedial Action Objectives

RAOs address the protection of human health and protection of the environment. The following five RAOs have been established for the Fox River and Green Bay Site.

- **RAO 1. Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay.** This RAO is intended to reduce PCB concentration in surface water as quickly as possible. The current water quality criteria for PCBs are 0.003 ng/L for the protection of human health and 0.012 ng/L for the protection of wild and domestic animals. Water quality criteria incorporate all routes of exposure assuming the maximum amount is ingested daily over a person's lifetime.
- **RAO 2. Protect humans who consume fish from exposure to COCs that exceed protective levels.** This RAO is intended to protect human health by targeting removal of fish consumption advisories as quickly as possible. DNR and EPA defined the expectation for the protection of human health as the likelihood for recreational anglers and high-intake fish consumers to consume fish within 10 years and 30 years, respectively, at an acceptable level of risk or without restrictions following completion of a remedy.
- **RAO 3. Protect ecological receptors from exposure to COCs above protective levels.** RAO3 is intended to protect ecological receptors like invertebrates, birds, fish, and mammals. DNR and EPA defined the ecological expectation as the likelihood of achieving safe ecological thresholds for fish-eating birds and mammals within 30 years following remedy completion. Although the FS did not identify a specific time frame for evaluating ecological protection, the 30-year figure was used as a measurement tool.
- **RAO 4. Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan.** The objective of this RAO is to reduce the transport of PCBs from the River into Green Bay and Lake Michigan as quickly as possible. DNR and EPA defined the transport expectation as a reduction in loading to Green Bay and Lake Michigan to levels comparable to the loading from other Lake Michigan tributaries. This RAO applies only to River reaches.
- **RAO 5. Minimize the downstream movement of PCBs during implementation of the remedy.** A remedy is to be completed within 10 years.

No numeric cleanup standards have been promulgated by the federal government or the State of Wisconsin for PCB-contaminated sediment. Therefore, site-specific RAOs to protect human and ecological health were developed based on available information and standards, such as applicable or relevant and appropriate requirements (ARARs), to be considered non-promulgated guidelines (TBC), and risk-based levels established using the human and ecological RAs. The following RAOs were established for the Site:

Remedial Action Levels - PCB remedial action levels were developed based on the Sediment Quality Thresholds (SQTs) derived in the RA for the Lower Fox River and Green Bay. SQTs are estimated concentrations that link risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. The PCB RALs considered are 0.125, 0.25, 0.5, 1.0, and 5.0 parts per million (ppm) for the Lower Fox River and 0.5, 1.0, and 5.0 ppm for Green Bay.

A range of RALs was considered in order to balance the feasibility as determined by implementability, effectiveness, duration, and cost of removing PCB-contaminated sediment down to each action level against the residual risk to human and ecological receptors after remediation. For each River reach or Bay zone, all of the sediment with PCB concentrations greater than the selected RAL is to be remediated. One of the outcomes of applying a specific RAL to a suite of active remedial alternatives is the recognition that Monitored Natural Recovery (MNR) may also be a component of the remedy. This was considered because when sediment is removed to a specific action level, some sediment with PCB concentrations above the SQTs will likely be left in place. MNR can also be a stand-alone remedy if it is determined to achieve sufficient protection within a reasonable time frame. As a result, each action level and each remedial alternative has an MNR component.

## 9.2 Applicable or Relevant and Appropriate Requirements (ARARs)

Section 121(d) of CERCLA requires that Superfund remedial actions meet ARARs. In addition to applicable requirements, the ARARs analysis that was conducted considered criteria, and relevant and appropriate standards that were useful in evaluating remedial alternatives. These non-promulgated guidelines and criteria are known as To Be Considered (TBCs). In contrast to ARARs, which are promulgated cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations; TBCs are guidelines and other criteria that have not been promulgated.

Location-specific ARARs establish restrictions on the management of waste or hazardous substances in specific protected locations, such as wetlands, floodplains, historic places, and sensitive habitats.

Action-specific ARARs are technology-based or activity-based requirements or limitations on actions taken with respect to remediation. These requirements are triggered by particular remedial activities that are selected to accomplish the remedial objectives. The action-specific ARARs indicate the way in which the selected alternative must be implemented as well as specify levels for discharge. See table 4-2 of the FS. Chemical specific ARARs are health- or risk-based numerical values or methodologies that establish concentration or discharge limits, or a basis for calculating such limits, for particular substances, pollutants or contaminants.

In addition to the water quality criteria, substantive requirements of National Pollutant Discharge Elimination System (NPDES), as implemented under Wisconsin administrative rules, would also be applicable to wastewaters that are planned to be discharged to the Fox River, which will require treatment. These wastewaters include liquids generated during construction activities such as dewatering liquids, excavation area liquids, and liquids generated during construction of any on-site consolidation area. Discharges to Publicly Owned Treatment Works (POTWs) may be pursued as an alternative discharge location. However, such discharges must also comply with limitations to ensure acceptable discharge from the POTW after treatment. The specific discharge levels will be determined during the design stage in coordination with WDNR.

Sediments removed from the Fox River may contain PCBs equal to or greater than 50 ppm. PCB sediment with concentrations less than 50 ppm will be managed as a solid waste in accordance with statutes and rules governing the disposal of solid waste in Wisconsin. PCB sediment with concentrations equal to or greater than 50 ppm will be managed in accordance with the Toxic Substances Control Act (TSCA) of 1976 (Appendix E of the Feasibility Study). The determination that material is subject to regulation under TSCA will be made post-removal but pre-disposal. Presently TSCA compliance would be achieved through the extension of the January 24, 1995 approval issued by EPA to WDNR pursuant 40 CFR 761.60(a)(5) under the authority of TSCA. This TSCA approval, granted by EPA Region 5, states that the disposal of PCB-contaminated sediment with concentrations equal to or greater than 50 ppm into an NR 500, WAC landfill that is also in compliance with the conditions of the TSCA approval, provides adequate protection to human health and the environment as required by 40 CFR 761.60(a)(5); and, will provide the same level of protection required by EPA, Region 5 and therefore is no less restrictive than TSCA. However, should other administrative rules pertaining to disposal under TSCA be in effect at the time that TSCA compliance decisions are made for the Fox River sediment, then compliance with those rules will be achieved.

# 10. DESCRIPTION OF ALTERNATIVES

Following development of the RAOs, WDNR conducted a rigorous screening and evaluation process in accordance with CERCLA and the NCP. First, potentially applicable remedial technologies or process options for addressing PCB-contaminated sediments in the Fox River and Green Bay were identified and screened (evaluated) based on effectiveness and technical implementability at the Site. Retained technologies were then evaluated in a second screening based on effectiveness, implementability and cost. After the second screening, the following four technologies were retained for consideration in the analysis of remedial alternatives: 1) no action, evaluation of which is required by the NCP; 2) Monitored Natural Recovery (MNR); 3) capping to the maximum extent practicable with dredging in areas where capping was not appropriate; and 4) removal/dredging (i.e., environmental dredging) followed by MNR.

Process options for treatment and disposal that were retained include dehalogenation, physical separation and solidification, vitrification and high-pressure oxidation.

After the technology screening, WDNR and EPA developed and screened remedial alternatives. A specified “cleanup value” or “action level” for PCBs in sediment was not developed for purposes of evaluating remedial alternatives. Because consumption of fish is the major pathway of concern, WDNR and EPA developed remedial goals based on PCB concentrations in fish (see Section 9). Therefore, remedial alternatives were evaluated based on their ability to reduce PCB concentrations in fish. PCB concentrations in fish are controlled by PCB concentrations in both the sediment and the water column and, therefore, sediment cleanup is considered the means to the goal of protecting human health and the environment.

For the capping alternative, locations where it was feasible were considered in determining where this technology could be applied based on criteria identified in section 6.4.4 of the Feasibility Study. For excavation alternatives, WDNR and EPA evaluated the following action levels for the Fox River: PCB concentrations of 0.125 ppm, 0.25 ppm, 0.5 ppm, 1.0 ppm, 5.0 ppm, and no action. These results were then compared to the RAOs, particularly RAOs 2 and 3, which deal with protection of human health and the environment. On the basis of that analysis and to achieve the risk reduction objectives using a consistent action level, 1.0 ppm was agreed upon as the appropriate remedial action level. In making this determination, the agencies relied on projections of the time necessary to achieve the risk reduction, the post-remediation surface-weighted average concentration (SWAC), and cost.

Table 15 shows that for the selected Action Level of 1.0 ppm, time to acceptable fish tissue concentrations for walleye, would be achieved within one year in OU 1. This compares to more than 50 years under a No Action alternative also shown in the table.

**Table 15 Years to Human Health and Ecological Thresholds for Lower Fox River at 1 ppm PCB Action Level and No Action in OU 1**

| Fish | Risk Level | Receptor | Estimated Years (for 1.0 ppm Action Level) | Estimated Years (for No Action) |
|---|---|---|---|---|
| Walleye[1] | RME[2] hazard index of 1.0 | Recreational Angler | <1 | 51 |
| Walleye | RME hazard index of 1.0 | High-intake fish consumer | 4 | 65 |
| Walleye | RME $10^{-5}$ cancer risk level | Recreational Angler | 9 | 84 |
| Walleye | RME $10^{-5}$ cancer risk level | High-intake fish consumer | 14 | 100 |
| Carp | NOAEC[3] | Carnivorous bird deformity | 14 | 100 |
| Carp | NOAEC | Piscivorous mammal | 29 | 100+ |

*1. Shaded row represents removal of fish advisories.*

*2. RME indicates the reasonable maximum exposure.*

*3. NOAEC is the no observed adverse effect concentration.*

It is estimated that it would take 40 years to remove fish advisories for OU 2, under the selected remedy, Monitored Natural Recovery. However, the removal of Deposit N (completed in a dredging demonstration project during 1998 and 1999) and Deposit DD (under consideration for remediation in the ROD for OU s 3-5) is not considered in the modeling upon which this estimate was made.

The SWAC is a measure of the surface (upper 10 cm) concentration against a given area. In terms of the Lower Fox River, this would be the average residual contaminant concentration in the upper 10 cm divided by the area of the Operable Unit. The SWAC calculation includes interdeposit areas. The estimated post-removal SWAC value for OU 1 at an action level of 1 ppm is 185 µg/kg.

The SWAC value provides a number that can be compared to the SQTs developed in the RA. SQTs are estimated concentrations that link risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. Human health and ecological SQTs for carp and walleye are listed in Tables 16 and 17, respectively.

**Table 16 Human Health Sediment Quality Threshold (SQT) Values**

| | | Recreational Angler | | High-Intake Fish Consumer | |
|---|---|---|---|---|---|
| | | RME[1] µg/kg | CTE[2] µg/kg | RME µg/kg | CTE µg/kg |
| **Cancer Risk at $10^{-5}$** | | | | | |
| Carp | | 16 | 180 | 11 | 57 |
| Walleye | | 21 | 143 | 14 | 75 |
| **Non-Cancer Risk (HI =1)** | | | | | |
| Carp | | 44 | 180 | 28 | 90 |
| Walleye | | 58 | 238 | 37 | 119 |

*1. RME indicates the reasonable maximum exposure;*
*2. CTE is the central tendency exposure.*

**Table 17 Ecological Sediment Quality Threshold (SQT) Values**

| | **NOAEC (**µg/kg**)** |
|---|---|
| Carp – fry growth and mortality | 363 |
| Walleye – fry growth and mortality | 176 |
| Common Tern – hatching success | 3,073 |
| Common Tern – deformity | 523 |
| Cormorant – hatching success | 997 |
| Cormorant – deformity | 170 |
| Bald Eagle – hatching success | 339 |
| Bald Eagle – deformity | 58 |
| Mink – reproduction and kit survival | 24 |

The volume of sediment and PCB mass that would be removed, as well as the cost to implement the remedy at the 1.0 ppm action level, were also considered. For OU 1 an estimated 784,200 cubic yards and 1,715 kilograms of PCBs would be removed. The cost for remediation of OU 1 is estimated to be $66.2 million.

WDNR and EPA selected six remedial alternatives for detailed analysis: No Action, Monitored Natural Recovery and Institutional Controls, Dredge and Off-Site Disposal, Dredge to a Confined Disposal Facility (CDF), Dredge and Vitrification, and In-situ Capping. These alternatives cover the range of viable approaches to remedial action and include a no-action alternative, as required by the NCP.

## 10.1 Description of Alternative Components

Remedial Alternatives **-** WDNR and U.S. EPA evaluated several alternatives to address contamination in the Lower Fox River and Green Bay. Because the level of contamination and size of the OUs vary, a specific proposed cleanup plan was developed for each OU. The FS outlines the process used to develop and screen appropriate technologies and alternatives for addressing PCB-contaminated sediment and provides detailed descriptions of the remedial alternatives. The suite of remedial alternatives is intended to represent the remedial alternatives that are available, not to be inclusive of all possible approaches. The proposed alternative for an Operable Unit may consist of any combination of the alternatives described below. Other implementable and effective alternatives could theoretically be used; however, a ROD amendment or Explanation of Significant Difference (ESD) would be required before another alternative could be substituted for the selected remedy.

**Alternative A: No Action -** A No Action alternative is included for all River reaches and Bay zones. This alternative involves taking no action. The No Action alternative is required by the National Contingency Plan, because it provides a basis for comparison with the alternatives for active remediation.

**Alternative B: Monitored Natural Recovery -** Similar to Alternative A, the MNR alternative relies on naturally occurring degradation, dispersion, and burial processes to reduce the toxicity, mobility, and volume of contaminants. However, the MNR option also includes a 40-year, long-term monitoring program for measuring PCB and mercury levels in water, sediment, invertebrates, fish, and birds to effectively determine achievement of and progress toward the RAOs. Until the RAOs are achieved, institutional controls are necessary to prevent exposure of human and biological receptors to contaminants. Land and water use restrictions, fishing restrictions and access restrictions may require local or state legislative action to prevent development or inappropriate usage of contaminated areas of the River. Institutional controls include measures that restrict access to or uses of a site. They typically consist of some combination of physical restraints (such as fences to limit access), legal restrictions (such as local ordinances and restrictive covenants that limit land development), and outreach activities (such as public education programs and health advisories).

**Alternative C: Dredge and Off-Site Disposal -** Alternative C includes the removal of sediment having PCB concentrations greater than the remedial action level using a hydraulic or mechanical dredge, dewatering the sediment either passively or mechanically, treating the water before discharging it back to the River, and then disposing of the sediment off site, transporting it by truck. Sediment disposal would be at a local landfill in compliance with the requirements of NR 500 Wisconsin Administrative Code (WAC), which regulates the disposal of waste and the WDNR's TSCA approval issued by EPA. EPA issued this approval under the authority of the federal TSCA. This approval allows for the disposal of PCB-contaminated sediment with concentrations equal to or greater than 50 mg/kg (ppm) in landfills that are licensed under the NR 500 rule series, WAC provided that certain requirements are met.

**Alternative D: Dredge to a Confined Disposal Facility (CDF) -** Alternative D includes the removal of sediment having PCB concentrations greater than the remedial action level to an on-site CDF for long-term disposal. A CDF is an engineered containment structure that provides both dewatering and a permanent disposal location for contaminated sediment. A CDF can be located in the water adjacent to the shore or at an upland location near the shore. Sediment with PCB concentrations equal to or greater than 50 mg/kg would not be disposed of in a CDF. Such sediments would be mechanically dredged for solidification and disposal at a solid waste landfill conforming to requirements defined by the state in the NR 500 rule series and WDNR's TSCA approval. Conceptual near-shore CDF locations were identified in OU 1.

**Alternative E: Dredge and Vitrification -** This alternative is similar to Alternative C except that all the dewatered sediment would be thermally treated using a vitrification process. Alternative E assumes that the residual material would be available for possible beneficial reuse after vitrification. Vitrification has been used as a representative thermal treatment process option and was included as an alternative due to a recently completed pilot-scale evaluation.

**Alternative F: In-situ (In-place) Capping -** Alternative F includes primarily sand capping to the maximum extent possible. The maximum extent of the capping action was defined in each River reach on the basis of site specific conditions such as water depth, average river current, river current under flood conditions, wave energy, ice scour, and boat traffic. Using these criteria, it was determined that capping alone is not a viable option to achieve the site RAOs. Where capping is viable, a 20-inch sand cap overlaid by 12 inches of graded armor stone was selected. Sediment that is not capped but still exceeds the action level would be hydraulically dredged to an on-site CDF, similar to Alternative D. In the FS, several cap designs were retained for possible application; design factors that influence the final selection of an in-situ cap include an evaluation of capping materials and cap thickness when applied in the field. In general, sandy sediment is a suitable capping material, with the additional option of armoring at locations with the potential for scouring and erosion. Laboratory tests developed in the past indicate that a minimum in-situ cap thickness of 12 inches (30 cm) is required to isolate contaminated sediment, as indicated in FS Section 7.1, page 7-4 to 7-5. Full-scale design would require consideration of currents during storm events, wave energy, and ice scour. A minimum river depth of 6 feet would be required (FS Section 7.1.1, page 7-5) for any location where a cap is proposed. Institutional controls and monitoring and maintenance are also components of this alternative. Institutional controls may be necessary to ensure the long-term integrity of the cap. Monitoring and maintenance would be required in perpetuity to ensure the integrity of the cap and the permanent isolation of the contaminants. Alternative F was determined not feasible for OU 2.

In evaluating the alternatives, WDNR and EPA considered the level of protection that would satisfy the concern of the natural resource trustees that future natural resource injuries be minimized. Many of the natural resource trustees cooperated in the development of the proposed plan and agreed with the combination of active remediation to a proposed cleanup level of 1.0 ppm PCBs and the use of Monitored Natural Recovery in areas where active remediation will not occur.

## 10.2 Key/Common Elements

The following discussion applies primarily to the dredging or dredging and capping alternatives.

**Phasing -** The first construction season of remedial dredging will include an extensive monitoring program of all operations. Monitoring data will be compared to performance standards developed during remedial design. Performance standards are likely to address (but may not be limited to) resuspension rates during dredging, production rates, and residuals after dredging, and community impacts *(*e.g., noise, air quality, odor, navigation). Data gathered will enable WDNR to determine if adjustments are needed to operations in the succeeding phase of dredging, or if performance standards need to be reevaluated. WDNR will make the data, as well as its final report evaluating the work with respect to the performance standards, available to the public.

**Institutional Controls -** Institutional controls (fish consumption advisories and fishing restrictions) would be utilized with the Monitored Natural Recovery, capping and removal alternatives. Institutional Controls are considered to be limited action alternatives, and therefore are not included in the No Action alternative.

**Source Control -** Point sources of contaminants to the Fox River have been effectively addressed by water discharge permits for the Fox River. Thus, no additional actions related to source control are necessary.

**Monitored Natural Recovery -** Natural recovery refers to the beneficial effects of natural processes that reduce surface sediment concentrations of PCBs. These processes include biodegradation, diffusion, dilution, sorption, volatilization, chemical and biochemical stabilization of contaminants, and burial by natural deposition of cleaner sediments. The primary mechanisms for natural recovery in the Fox River and Green Bay are desorption and dispersion in the water column (i.e., as a dissolved constituent), burial, and sediment resuspension and transport. Biodegradation is a negligible contributor to the lowering of PCB concentrations and is not a factor for mercury. The relative importance of each of these mechanisms in reducing PCB concentrations in the Fox River and Green Bay is not easily estimated based on available data. Some or all of these processes may be occurring at varying rates at any given time and location within the River or Bay. During the design phase, a monitoring program will be developed to measure the net effects of the natural attenuation processes after remedial activities are completed until the remediation goals are reached.

**Sediment Concentrations -** Sediments that may significantly contribute to the PCB levels in fish, both now and in the future, are considered principal threats. The determination of the significance of the sediment contribution to fish is based primarily on model projections, in conjunction with geochemical and statistical analyses. The model projections indicate that the significance of the sediment contribution to PCB fish tissue levels varies by Operable Unit; therefore, the sediment levels that are considered principal threats will correspondingly vary by Operable Unit.

**Treatment -** Conventional treatment technologies, such as thermal desorption, are technically feasible; however, the associated costs would be substantially greater than off-site landfill disposal. However, vitrification of sediments is feasible and as such is considered a possible alternative to the current plans for conventional disposal in an approved, licensed landfill. Materials that would be processed using vitrification technology could be beneficially re-used.

**Sediment Processing/Transfer Facilities -** It is expected that sediment processing/transfer facilities would be established to handle materials from the environmental dredging process. The locations of these facilities will be determined during the remedial design phase of the remedy considering engineering issues (such as those associated with the type of dredging selected), property issues, noise, air impacts and other appropriate factors. Although it is projected that these facilities would be land-based, water-based facilities will also be evaluated.

Dredged sediments will be mechanically dewatered and loaded onto trucks for transport to disposal facilities.

Water that is separated from the dredged sediment will undergo treatment to remove fine sediment particles and dissolved PCBs. Ultimately, the water will be discharged back into the Fox River in compliance with the substantive requirements of the State of Wisconsin Pollutant Discharge Elimination System, which is an ARAR for this Site.

**Transportation -** Dredged materials will be transported from the dredging site to the sediment processing/transfer facilities by barge or in-river pipeline. Transportation from the sediment processing/transfer facilities to disposal facilities will be by truck.

**Disposal -** Disposal of PCB contaminated sediment from OU 1 will be to either an existing upland landfill or into a newly constructed or modified landfill designed to receive the dewatered sediment. ARARs/TBCs specific to the landfill option include the siting requirements for a landfill (Chapter 289, Wisconsin Statutes) and the technical requirements for construction, operation, and closure of a landfill in the NR 500 rule series, WAC.

Sediments removed from the Fox River may contain PCBs equal to or greater than 50 ppm. PCB sediment with concentrations less than 50 ppm will be managed as a solid waste in accordance with statutes and rules governing the disposal of solid waste in Wisconsin. PCB sediment with concentrations equal to or greater than 50 ppm will be managed in accordance with the Toxic Substances Control Act of 1976 (Appendix E of the Feasibility Study). Presently TSCA compliance would be achieved through the extension of the January 24, 1995 approval issued by EPA to WDNR pursuant 40 CFR 761.60(a)(5) under the authority of TSCA. This TSCA approval, granted by EPA Region 5, states that the disposal of PCB-contaminated sediment with concentrations equal to or greater than 50 ppm into an NR 500, WAC landfill that is also in compliance with the conditions of the TSCA approval, provides adequate protection to human health and the environment as required by 40 CFR 761.60(a)(5); and, will provide the same level of protection required by EPA, Region 5 and therefore is no less restrictive than TCSA. However, should other administrative rules pertaining to disposal under TSCA be in effect at the time that TSCA compliance decisions are made for the Fox River sediment, then compliance with those rules will be achieved.

Therefore, this disposal method meets the TSCA regulatory requirement 40 CFR 761.61(c) that the risk-based method for disposal of PCB remediation waste does not pose an unreasonable risk of injury to health and the environment.

Although off-site landfilling is anticipated, vitrification and beneficial re-use of dredged excavated sediments will be evaluated during the design phase. Value engineering to reduce waste volumes (that will also reduce costs) will be explored and, if appropriate, finalized during remedial design.

**Monitoring -** Short- and long-term (i.e., pre-, during, and post-construction) monitoring programs will be developed to ensure compliance with performance standards and protection of human health and the environment. The types and frequency of pre-construction monitoring will be developed during remedial design. Plans for monitoring during and after construction will be developed during the remedial design and modified during and after construction as appropriate. This approach is consistent with the NRC Report recommendation that long-term monitoring evaluate the effectiveness of the remedial action as well as ensure protection of public health and the environment.

## 11. COMPARATIVE ANALYSIS OF ALTERNATIVES

In selecting a remedy for a site, WDNR and EPA consider the factors set forth in CERCLA § 121, 42 U.S.C. § 9621, by conducting a detailed analysis of the viable remedial alternatives pursuant to the NCP, 40 CFR § 300.430(e)(9), EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies, OSWER Directive 9355.3-01, and EPA's 'A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents, OSWER 9200.1-23.P. The detailed analysis consists of an assessment of the individual alternatives against each of nine evaluation criteria (two threshold, five primary balancing and two modifying criteria) and a comparative analysis focusing upon the relative performance of each alternative against those criteria.

### Threshold Criteria

1. **Overall Protection of Human Health and the Environment** addresses whether a remedy provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced or controlled through treatment, engineering, or institutional controls. The selected remedy must meet this criterion.
2. **Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)** addresses whether a remedy will meet applicable or relevant and appropriate federal and state environmental laws and/or justifies a waiver from such requirements. The selected remedy must meet this criterion or a waiver of the ARAR must be attained.

### Primary Balancing Criteria

3. **Long-Term Effectiveness and Permanence** refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met.
4. **Reduction of Toxicity, Mobility, or Volume Through Treatment** addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at the site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.
5. **Short-Term Effectiveness** addresses the period of time needed to achieve protection and any adverse impacts on human health and the environment that may be posed, until cleanup levels are achieved.

6. **Implementability** is the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement a particular option.

7. **Cost** includes estimated capital costs, annual operation and maintenance costs (assuming a 30-year time period), and net present value of capital and operation and maintenance costs.

**Modifying Criteria**

8. **Agency Acceptance** considers whether the support agency, EPA in this instance, concurs with the lead agency's remedy selection and the analyses and recommendations of the RI/FS and the proposed plan.

9. **Community Acceptance** addresses the public's general response to the remedial alternatives and proposed plan. The ROD includes a responsiveness summary that presents public comments and the WDNR and EPA responses to those comments. The level of community acceptance of the selected alternative is outlined in the Responsiveness Summary (see Appendix A).

## 11.1 Operable Unit 1 (Little Lake Butte des Morts)

Table 18 summarizes the evaluation for OU 1 alternatives and how each alternative meets, or does not meet requirements for each of the nine criteria described above. A detailed comparative analysis for all alternatives follows.

**Table 18 Operable Unit 1. Little Lake Butte des Morts Alternatives**

| | | | | **Selected Alternative** | | | |
|---|---|---|---|---|---|---|---|
| Yes = Fully meets criteria<br>Partial = Partially meets criteria<br>No = Does not meet criteria | Alternative A<br>No Action | Alternative B<br>Monitored Natural Recovery | Alternative C1<br>Dredge with off site disposal | Alternative C2<br>Dredging with off site disposal | Alternative D<br>Dredge to a Confined Disposal Facility | Alternative E<br>Dredge and Vitrification | Alternative F<br>In Situ Capping |
| 1. Overall protection of human health and the environment | No | No | Yes | Yes | Yes | Yes | Yes |
| 2. Compliance with Applicable or Relevant & Appropriate Requirements | No | Partial | Yes | Yes | Yes | Yes | Yes |
| 3. Long-term Effectiveness and Permanence | No | No | Yes | Yes | Yes | Yes | Partial |
| 4. Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment | No | No | Yes | Yes | Yes | Yes | Partial |
| 5. Short-term Effectiveness | No | No | Yes | Yes | Partial | Partial | Partial |

| Yes = Fully meets criteria<br>Partial = Partially meets criteria<br>No = Does not meet criteria | Alternative A<br>No Action | Alternative B<br>Monitored Natural Recovery | Alternative C1<br>Dredge with off site disposal | **Selected Alternative**<br>Alternative C2<br>Dredging with off site disposal | Alternative D<br>Dredge to a Confined Disposal Facility | Alternative E<br>Dredge and Vitrification | Alternative F<br>In Situ Capping |
|---|---|---|---|---|---|---|---|
| 6. Implementability | Yes | Yes | Yes | Yes | Partial | Partial | Partial |
| 7. Cost (millions of $) | $ 4.5 | $ 9.9 | $ 116.7 | $ 66.2 | $ 68.0 | $ 63.6.0 | $ 90.5 |
| 8. Agency Acceptance | The WDNR has been the lead agency in developing the RI/FS and the ROD. Both WDNR and EPA support the selected alternative for this OU at the 1.0 ppm action level. | | | | | | |
| 9. Community Acceptance | The level of community acceptance of the selected alternative is outlined in the Responsiveness Summary. | | | | | | |

### 11.1.1 Threshold Criteria for Operable Unit 1

**Protection of Human Health and the Environment**

The primary risk to human health associated with the contaminated sediment is consumption of fish. The primary risk to the environment is the bioaccumulation of PCBs from the consumption of fish or, for invertebrates, the direct ingestion/consumption of sediment. Protection of human health and the environment were evaluated by residual risk in surface sediment using five lines of evidence:

- Residual PCB concentrations in surficial sediment using surface-weighted averaging after completion of a remedy;
- Average PCB concentrations in surface water;
- The projected number of years required to reach safe consumption of fish;
- The projected number of years required to reach a surface sediment concentration protective of fish or other biota, and
- PCB loadings to downstream areas and total mass contained or removed.

Each of these is discussed below.

<u>Residual PCB concentrations in surficial sediment and surface water</u>

As shown in Table 19 below, substantial reductions in the average concentration of surficial sediment and in surface water for OU 1 is achieved by all active remediation alternatives (C1, C2, D, E and F) when compared to the No Action and MNR alternatives (A and B). The implementation of active remediation alternatives results in a 95 percent reduction in residual PCB concentrations in surface sediment using surface-weighted averaging after completion of the Alternatives C1, C2, D, E or F, when compared to the No Action or MNR Alternatives, respectively (i.e., 3.699 versus 0.185 ppm, respectively -- see Table 19). Similarly, the estimated surface water concentrations 30-years after remediation is reduced 94 percent for active remediation alternatives (B, C1, C2, D, E and F), relative to No Action and Monitored Natural Recovery (A, and B, respectively) – i.e., 2.99 versus 0.18 ppm, respectively -- see Table 19.

**Table 19 Post-Remediation Sediment and Surface Water Concentrations in OU 1**

| Alternative | Average PCB Concentrations in Surficial Sediments (ppm) | Estimated Surface Water Concentrations 30-years after Remediation (ng/L) |
|---|---|---|
| A, B | 3.699 | 2.99 |
| C1, C2, D, E, F | 0.185 | 0.18 |

*Data is from FS Tables 5-4, and 8-5B.*

Time to reach acceptable fish tissue concentrations

Substantial reductions in the time when humans could safely consume fish are achieved by active remediation alternatives (C1, C2, D, E, and F), when compared to the No Action and Monitored Natural Recovery (MNR) alternatives (A and B). The implementation of active remediation alternatives results in an 86 percent to 99 percent reduction in the time required to reach acceptable fish tissue concentrations in walleye when compared to the No Action or MNR alternatives (i.e., 1 to 14 years for active remediation versus 51 to 100 years for No Action or MNR – see Table 20). Recovery times for additional human health receptors are presented the FS, Chapter 8, Table 8-6.

**Table 20 Time Achieve Acceptable Fish Tissue Concentrations for Walleye in OU 1**

| Fish | Receptor | Risk Level Goal | Estimated Years to Achieve | |
|---|---|---|---|---|
| | | | Alternatives C1, C2, D, E, F | Alternatives A, B |
| Walleye | Recreational Angler | RME Hazard Index of 1.0 | <1 | 51 |
| Walleye | High Intake Fish Consumer | RME Hazard Index of 1.0 | 4 | 65 |
| Walleye | Recreational Angler | RME $10^{-5}$ cancer risk level | 9 | 84 |
| Walleye | High Intake Fish Consumer | RME $10^{-5}$ cancer risk level | 14 | 100 |

*Data is from FS Table 8-14.*

Time required to achieve surface sediment concentration protective of fish or other biota

Substantial reductions in the time required to reach protective levels for ecological receptors are achieved by all active remediation alternatives (C1, C2, D, E, and F) relative to the No Action and MNR alternatives. For receptors representative of fish or other biota, implementation of active remediation alternatives results in a 40 percent to 86 percent reduction relative to No Action or MNR (i.e., 14 to 60 years for active remediation versus 100 years or more for No Action and MNR, shown in Table 21, below). Recovery times for additional ecological receptors are presented in the FS, Chapter 8, Table 8-6.

**Table 21 Time Required to Achieve Protective Levels in Sediments for Representative Ecological Receptors in OU 1**

| Fish | Receptor | Risk Level Goal | Estimated years to achieve | |
|---|---|---|---|---|
| | | | Alternatives C1, C2, D, E, F | Alternatives A, B |
| Carp | Carnivorous bird | NOAEC | 14 | 100 |
| Carp | Piscivorous mammal | NOAEC | 29 | >100 |
| Sediment | Sediment invertebrate | TEL | 60 | >100 |

*Data is from FS Table 8-16.*

PCB loadings to downstream areas and total mass contained or removed
Reduction of the PCB load transported over the Appleton Dam into the downstream areas of the Fox River is a measure of the overall protection of human health and the environment. Reduced PCB loading from OU 1 will ultimately contribute to downstream reduction of concentrations of PCBs in sediment, water and fish, and thereby reduce risk to humans and ecological receptors in the Fox River. After implementation of active remedial alternatives (C1, C2, D, E, and F) estimates for releases over the Appleton Dam would be reduced from 88 pounds/year presently to 1.5 pounds/year 30 years after completion of remediation, compared to 25 pounds for the No Action and MNR alternatives (also after 30 years). Thus the active remedial alternatives would give a 94 percent reduction in loadings relative to No Action and MNR.

**Summary**

The active remediation alternatives provide a substantially more protective remedy than the No Action and MNR alternatives. The No Action and MNR Alternatives are not protective of human health and the environment.

### Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Section 121 (d) of CERCLA and NCP §300.430(f)(1)(ii)(B) requires that remedial actions at CERCLA sites attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA section 121(d)(4).

Compliance with ARARs addresses whether a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for invoking a waiver.

The ARAR discussion, below, is divided by the different operational components of the alternatives (Table 22, and discussion below), as various components are utilized in an essentially the same manner for some alternatives and apply equally to those alternatives with a common component. There is also additional discussion of ARARs in Section 14.2.

**Table 22 Operational Components for OU 1 Alternatives**

| | | **Alternatives** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **A** | **B** | **C1** | **C2** | **D** | **E** | **F** |
| Removal | | | | X | X | X | X | X |
| Dewatering | Mechanical | | | | X | | | |
| | Passive | | | X | | X | X | X |
| Sediment Treatment | | | | * | * | | X | * |
| Water Treatment | | | | X | X | X | X | X |
| Trucking or Rail Transportation | | | | X | X | X | X | X |
| Disposal | Upland | | | X | X | X** | (residuals) | X |
| | In-water CDF | | | | | X | | |
| Capping | | | | | | | | X |

*X: Required activity for alternative.*
** Possible supplement.*
*** Upland disposal for this alternative would only be for sediments with PCB concentrations equal to or greater than 50 ppm (16,165 cubic yards of 800,357). Sediments with concentrations less than 50 ppm (784,192 cubic yards) would be disposed in an in-water CDF.*

A description of the components listed in Table 22, above follows:

- **Removal.** The removal technology utilized for active remedial alternatives Alternatives C1, C2, D, E, and F is dredging (although Alternative F also includes capping). The ARARs that directly relate to the removal of sediment from the Lower Fox River and Green Bay concern the protection of surface water (NR 322, 200, and 220 through 297). The surface water ARARs limit the discharge of PCBs into the receiving water bodies so that water quality is not adversely affected. These ARARs will be achieved by all active remedial alternatives.
- **Dewatering and Water Treatment.**
  - Mechanical dewatering would be utilized for Alternative C2. Discharge requirements (NR 200 and 220 through 297, WAC) are set forth for the discharge of water to publicly owned treatment works (POTWs) and to navigable waters such as the Lower Fox River (NR 105 and 106, WAC). Discharges from prior remedial activities on the Lower Fox River provide an indication of the treatment requirements for discharging effluent water to the Lower Fox River or to a POTW. Another requirement covers stormwater discharge. A potentially important ARAR (NR 108, WAC) relates to the construction of a wastewater treatment facility specifically to treat water from remedial activities.
  - Passive dewatering ponds would be part of Alternative C2, D, E and F and would be constructed under the wastewater ARAR (NR 213, WAC), which associated with wastewater treatment lagoons. Based on previous experience gained during the SMU 56/57 pilot dredging project, ARARs associated with passive dewatering lagoons are achievable.
- **Ex-Situ (Off-site) Treatment.** ARARs specific to vitrification technology (Alternative E) relate to the air emission and permitting requirements of thermal treatment units (40 CFR 701 and NR 400 through 499). In addition, the thermal unit must meet performance requirements in NR 157 for the efficient treatment of PCB sediment. These ARARs would be met.
- **Transportation.** The likely method for transporting PCB sediment to upland disposal locations for Alternatives C1, C2, and F is by trucking to the disposal facility, although other transportation methods could be used if it is determined during design that there are better methods. ARARs and TBCs important to this process option include the requirements to prevent spills and releases of PCB materials (NR 140 and 157, WAC). Two ARARs applicable only to the trucking method include Wisconsin Department of Transportation (WDOT) requirements for the shipping of PCB materials and NR 157 shipping requirements. ARARs and TBCs related to in-water transportation activities (i.e., piping) include the protection of surface water (NR 322, 200, and 220 through 297,WAC). Alternatives C1, C2 and F will comply with these ARARs.
- **Disposal.** For Alternatives C1, C2, and F, disposal of contaminated sediment removed (i.e., dredged) from OU 1 will be disposed at either an existing upland landfill or in a newly constructed or modified landfill designed to receive the dewatered sediment. ARARs specific to this process option include the siting requirements for a landfill (Chapter 289, Wisconsin Statutes) and the technical requirements for construction, operation, and closure of a landfill in the NR 500 rule series, WAC. For contaminated sediments with PCB concentrations equal to or greater than 50 ppm, disposal will comply with the Toxic Substances Control Act, 40CFR Part 761. Alternative D would also have a relatively small portion (i.e., 2 percent) of dredged materials with concentrations equal to or greater than 50 ppm that would also be disposed at a TSCA compliant upland landfill. General disposal requirements for PCB-containing sediments are simplified by the EPA's current approval requirements for placing TSCA-level PCB-containing material in a state-licensed landfill. In

all cases, for sediment to be disposed of at a local landfill, the landfill must be in compliance with the requirements of the NR 500 WAC series regulating the disposal of waste and WDNR's TSCA approval issued by EPA. This EPA approval currently allows for the disposal of PCB-contaminated sediment with concentrations equal to or greater than 50 mg/kg in landfills licensed under the NR 500 rule series, WAC, provided that certain technical and administrative requirements are met. These ARARs will be met by alternatives C1, C2 and F.

- **Capping.** For Alternative F, some sediments would be capped in-place, primarily in the central (deeper water) portions of OU 1. This would require compliance with Section 10 of the Rivers and Harbor Act of 1899 (22 CFR 403), and may require compliance with the Wisconsin Statutes Chapter 30 (defining riparian rights of upland owners which extend to the center of a stream). If the capping area is considered to be located in a lake, then the State, through the Board of Commissioners of Public Lands, may lease "rights of the beds of lakes and rights to fill in beds of lakes or navigable streams." It is expected that these ARARS would be met.

### 11.1.2 Balancing Criteria for Operable Unit 1

**Long-Term Effectiveness and Permanence**

Reduction of Residual Risk
The No Action and MNR alternatives result in a continuation of the degraded condition of the sediments and surface water quality of Little Lake Butte des Mort (OU 1), for at least several decades. The No Action and MNR Alternatives do not eliminate PCBs from the River and do not reduce PCB levels in fish to acceptable levels for the foreseeable future.

Alternatives C1, C2, D, E and F reduce residual risk through removal or containment of 800,357 cubic yards of sediments containing approximately 1715 kg (about 3800 pounds) of PCBs over an area of 526 acres. The reduction in the time required to reach acceptable fish tissue concentrations ranges from 86 percent to 99 percent (i.e., 1 to 14 years for active remediation and 51 to 100 years for No Action/MNR – see Table 20).

Adequacy of Controls
The No Action and MNR alternatives do not produce reduction in human risk and exposure in the foreseeable future, unlike active engineering controls. Additionally, fish consumption surveys indicate that 50 percent of anglers do not follow fish advisories. Therefore, existing institutional controls do not adequately reduce human exposure to PCBs from consumption of contaminated fish. In addition, institutional controls are not protective for ecological receptors (e.g., the birds, mammals and fish). Given the survey data, it is unlikely that sole reliance on these types of controls would be reliable in the long term to ensure human health and ecological protection.

The active remediation alternatives (C1, C2, D, and E) provide for the removal of most of the PCB-contaminated sediments in OU 1. Alternative F also removes a large portion of PCB-contaminated sediments and provides for an engineered cap over approximately 20 percent of contaminated deposits in OU 1. Like the MNR alternative, Alternative F also requires institutional controls such as Site use restrictions in capped areas (e.g., prohibition of sediment disturbance activities). Although institutional controls would still be required for the two removal alternatives, the risk to consumers of fish would be greatly reduced by these alternatives.
All alternatives would require institutional controls, such as the fish consumption advisories and fishing restrictions until remedial action objectives were met at a future date, but they are unlikely to require additional Site use restrictions after removal activities are completed.

All alternatives will require some degree of monitoring. Monitoring programs will be developed, as appropriate, for all phases of the project.

Alternatives C1, C2, D and F rely on engineering controls at the disposal facility. Properly designed and managed landfills provide proven, reliable controls for long-term disposal for Alternatives C1, C2 and F (which have off-site landfill disposal). Alternative F would also require a long-term operation and maintenance plan to ensure containment of PCBs in perpetuity. Alternative D would require on-site engineering controls at an in-water disposal facility. Long-term monitoring and maintenance are included in operation of the landfill and confined disposal facility. The final disposition of contaminated sediments is listed in the following table.

**Table 23 Final Disposition of Contaminated Sediments in OU 1**

| | Alternatives (cubic yards) | | | | | |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C1/C2** | **D** | **E** | **F** |
| Treated and residual disposal | 0 | 0 | 0 | 0 | 784,192 | 0 |
| Removed and disposed at upland landfill | 0 | 0 | 784,192 | 16,165 | 0 | 16,645 |
| Removed and disposed at in-water CDF (on-site) | 0 | 0 | 0 | 768,027 | 0 | 619,381 |
| Capped in-place | 0 | 0 | 0 | 0 | 0 | 148,646 |

*Data is from FS Table 7-2.*

<u>Reliability of Controls</u>
For the active remedies (Alternatives C1, C2, D, E and F), and MNR, fish consumption advisories and fishing restrictions will continue to provide some protection of human health until PCB concentrations in fish are reduced to the point where the fish consumption advisories and fishing restrictions can be relaxed or lifted. However, in the interim, these controls will only provide an uncertain measure of protection. Among the active alternatives, sediment capping, sediment removal (dredging and excavation), and off-site disposal/treatment of removed sediments are all established technologies.

The capping portion of Alternative F relies upon proper design, placement and maintenance of the cap in perpetuity for its effectiveness, continued performance and reliability. A cap integrity monitoring and maintenance program would provide reasonable reliability, although there are inherent challenges in monitoring and maintaining a cap in the Fox River riverine environment. The capping portion of Alternative F (see Table 23, above for the volume of capped contaminated sediments) may not be as reliable as the removal alternatives due to the unknown potential for damage to the cap, potentially exposing PCBs. In addition, the capping component of Alternative F is vulnerable to a catastrophic flow event, such as might be seen during a 500-year flood or a dam failure. However, with proper design and maintenance, these risks can be minimized.

In general, Alternatives C1 and C2, D and E are the most reliable, as there is little or no long-term additional on-site maintenance associated with the remedial work. These Alternatives permanently remove the greatest amount of contaminated sediment and PCBs from the River, and achieve the greatest reduction of the potential scour-driven resuspension of PCB-contaminated sediments. However, Alternative F is also considered to be sufficiently reliable.

Summary

Based on the above analysis of reduction in residual risk and adequacy and reliability of controls, the five active remediation alternatives (C1, C2, D, E and F) are superior to the No Action and MNR alternatives due to the greater risk reduction and mass of PCBs removed from the River. The five active remediation alternatives are similar to each other in terms of risk reduction with C1, C2, and E being the most effective over time. EPA's analysis of residual risk for each alternative is consistent with the National Research Council (NRC) report recommendation to consider options to reduce risk and to consider residual risks associated with material left behind.

Reduction of Toxicity, Mobility, and Volume

Reduction in Toxicity, Mobility, or Volume of Contaminants through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment and the amount of contamination present.

The No Action and MNR alternatives do not involve any containment or removal of contaminants from Little Lake Butte des Morts sediments. The No Action and MNR alternatives rely on natural attenuation processes such as burial by cleaner sediments, biodegradation, bioturbation and dilution to reduce concentrations of PCBs in sediments and surface water.

Natural degradation processes were not found to be effective in reducing PCB concentrations or toxicity in Fox River sediments (FS Appendix F, "Dechlorination Memorandum"). Nevertheless, concentrations of PCBs in fish populations will respond slowly over time to slow natural decreases in concentrations in sediments and surface water due primarily to dilution and the burial of contaminated sediments by cleaner sediments.

For Alternative F, the mobility of the PCBs in capped areas (approximately 135 acres) would be reduced because these PCBs are sequestered under the cap. However, capping does not satisfy the CERCLA statutory preference for treatment. In addition, there is no reduction in the toxicity or volume of the PCBs under the cap. Under this alternative, the mass of PCBs and the volume of contaminated sediments within Little Lake Butte des Morts are permanently reduced because approximately 620,000 cubic yards of sediment would be removed, and approximately 150,000 cubic yards would be contained under a cap in OU 1. A total of approximately 1715 kg (about 3770 lbs) of total PCBs would be removed or isolated from the ecosystem by this alternative. In addition, after construction of the remedy is completed, natural attenuation processes could provide additional reductions in PCB concentrations in the remaining sediments and surface water.

For Alternatives C1, C2, D, and E, the mass of PCBs and volume of contaminated sediments in Little Lake Butte des Morts are permanently reduced because sediment volumes of approximately 784,000 cubic yards of contaminated sediment, containing a mass of total PCBs of approximately 1715 kg (about 3770 lbs) would be removed from the ecosystem. Also, as stated for Alternative F, after construction of the remedy is completed, natural attenuation processes would provide additional reductions in PCB concentrations in the remaining sediments and surface water.

While the active remedial alternatives (Alternatives C1, C2, D and F) would permanently remove large volumes of PCBs from the River (thereby reducing their mobility), they do not satisfy the statutory preference for treatment as a principal element of the remedy. Given the volume of material to be removed, treatment of the dredged material prior to off-site disposal may not be cost-effective, other than the stabilization of the sediments for handling purposes. During remedial design, WDNR will further consider the cost-effectiveness of vitrification for dredged material. Alternative E in the FS has been revised to consider vitrification. Vitrification would reduce toxicity, mobility, and volume, and the glass aggregate product would be available for beneficial re-use.

Short-Term Effectiveness

Short-term Effectiveness relates to the length of time needed to implement an alternative and the risks the alternative poses to workers, residents and the environment during implementation up until the time that remediation levels are achieved.

Length of Time Needed to Implement the Remedy

The implementation times for the active alternatives are approximately 6 years for Alternatives C1 and C2, D, E and approximately 5 years for Alternative F. This represents the estimated time required for mobilization, operation and demobilization of the remedial work, but does not include the time required for long-term monitoring or O&M. The No Action and MNR alternatives do not involve any active remediation and therefore require no time to implement.

Protection of the Community and Workers During Remedial Action

No construction activities are associated with the remediation of sediments for the No Action and MNR alternatives, so neither alternative increases or decreases the short-term potential for direct contact with or ingestion and inhalation of PCBs from the surface water and sediments.

**Community Protection.** Access to sediment processing/transfer facilities and process and treatment areas under the active remediation alternatives (C1, C2, D, E and F) will be restricted to authorized personnel. Controlling access to the dredging locations and sediment processing/transfer facilities along with monitoring and engineering controls developed during the design phase will minimize potential short-term risks to the community. The design will also provide for appropriate control of air emissions, noise and light through the use of appropriate equipment that meets all applicable standards. Compliance with these design provisions will be monitored during construction, operation and demobilization. Vehicular traffic will increase due to workers and supply deliveries at the sediment processing and transfer facilities. These effects are likely to be minimal, in part because the transportation of sediments for disposal will take place within the Fox River area. If a beneficial use of some portion of the dredged material is arranged, then an appropriate transportation method will be determined (e.g, rail, truck, or barge).

For the active remediation alternatives (Alternative C1, C2, D, E and F), work in the River will also be designed with provisions for control of air emissions, noise and light. Work areas will be isolated (access-restricted), with an adequate buffer zone so that pleasure craft can safely avoid these areas. Environmental dredging in the River will be conducted at times and in ways to minimize disruption to river traffic. Targeted dredging will be sequenced and directed to ensure minimal impacts to navigation within the River. To help ensure that navigation is not impeded, WDNR and EPA will consult with the local authorities during remedial design and construction phases on issues related River usage, and other remedy-related activities within Little Lake Butte des Morts. Discrete areas of the River will be subject to dredging and related activities only over short periods of time; once an area is dredged, dredging equipment will move to another area, thereby minimizing locational impacts.

Based on air monitoring for the SMU 56/57 demonstration project, air emissions at dredging sites and at land-based facilities are expected to be minimal. Action levels will be established, monitoring conducted as required, and appropriate engineering control measures employed to ensure that any air releases do not exceed acceptable levels.

Vehicles used for the transportation of hazardous waste will be designed and operated in conformance with State and local regulations. WDNR and EPA will provide the community and local government the opportunity to have input on plans related to the off- Site transportation of hazardous wastes. This approach is consistent with the NRC recommendation to involve the local communities in risk management decisions.

WDNR and EPA believe that implementation of any of the active remediation alternatives (C1, C2, D, E and F) will have little if any adverse impact on local businesses or recreational opportunities. Indeed, WDNR and EPA believe that the remedy will have substantial positive economic impacts on local communities and will facilitate enhanced recreational activities in and along the River. To the extent that any adverse local impacts do occur, WDNR and EPA expect that they will be short-term and manageable. Moreover, the Agencies believe that any such impacts will far outweigh the long-term benefits of the remediation on human health and the environment.

**Worker Protection.** For the No Action and MNR alternatives, occupational risks to persons performing the sampling activities (for the 5-year reviews) will be unchanged from current levels. There is some minimal increase in occupational risk associated with the MNR alternative due to the greater degree of sampling involved in the River.

For the five active remediation alternatives (C1, C2, D, E and F), potential occupational risks to Site workers from direct contact, ingestion and inhalation of PCBs from the surface water and sediments, as well as routine physical hazards associated with construction work and working on water, are higher than for the No Action and MNR alternatives. For these alternatives, as well as the No Action and MNR alternatives, personnel will follow a site-specific health and safety plan and OSHA health and safety procedures and wear the necessary personal protective equipment; thus, no unacceptable risks would be posed to workers during the implementation of the remedies.

In summary, the active remedial alternatives would not pose significant risk to the nearby communities. A short-term risk to the community and site workers may be possible as a result of potential air emissions and noise from construction equipment, dewatering operations, and hauling activities. However, as successfully shown during the Lower Fox River demonstration dredging projects, these risks can be effectively managed/minimized by: (1) coordinating with and involving the community; (2) limiting work hours; and (3) establishing buffer zones around the work areas; as well as through (4) using experienced contractors who would assist project design.

<u>Environmental Impacts of Remedy and Controls</u>
Environmental impacts consist of PCB releases from removed sediment into the air and water. As successfully shown during the Lower Fox River demonstration dredging projects, environmental releases will be minimized during remediation by (1) treating water prior to discharge; (2) controlling storm water run-on and runoff from staging and work areas; and (3) utilizing removal techniques that minimize losses; as well as through (4) the possible use of silt curtains where necessary to reduce the potential downstream transport of PCBs.

Habitat impacts from active remedial activities (Alternatives C1, C2, D, E and F) are expected to be minimal, as the benthic community should recover relatively quickly (see White Paper Number 8 for details) from dredging activities. Additionally, dredging remediation can result in collateral benefits in the course of mitigation, including removal of nuisance species, reintroduction of native species, aeration of compacted and anaerobic soils and other enhancements of submerged habitats. For the capping portion of Alternative F, there could be similar effects on aquatic vegetation and benthic invertebrate and fish communities, but recovery of benthic invertebrate communities would likely be slower (relative to recovery from dredging) due to changes in the sub aqueous habitat to sand and rock as well as decreases in organic content of the sediment decreasing the organic content of the sediment.

Potential Adverse Environmental Impacts During Construction
No construction activities associated with the River sediments are conducted for the No Action and MNR alternatives. Neither continuation of the existing limited sampling activities for the No Action alternative nor the increased monitoring program for the MNR alternative is anticipated to have any adverse effect on the environment, beyond that already caused by the PCB contamination of the sediments and the ongoing releases of PCBs from those sediments in Little Lake Butte des Morts. For the five active remediation alternatives (C1, C2, D, E and F), the release of PCBs from the contaminated sediments into the surface water during construction (dredging and cap placement), will be controlled by operational practices (e.g., control of sediment removal rates, use of environmental dredges and possible use of sediment barriers). Although precautions to minimize resuspension will be taken, it is likely that there could be a localized temporary increase in suspended PCB concentrations in the water column and possibly in fish PCB body burdens. Analysis of results from projects on Deposit N and SMU 56/57, and comparison to yearly sediment resuspension rates, as well as resuspension quantities during yearly high flow events, shows the expected resuspension due to dredging to be well within the variability that normally occurs on a yearly basis. Analysis of results from other dredging projects indicates that releases from environmental dredging are relatively insignificant (substantially less than 1 percent of the mass of contaminants). The performance standards and attendant monitoring program developed during design will ensure that dredging operations are performed consistent with the environmental and public health goals of the project. This was readily achieved on the Deposit N and SMU 56/57 projects and is expected to be feasible for other River dredging activities.

Dredging activities may result in short-term temporary impacts to aquatic and wildlife habitat of the Little Lake Butte des Morts, but as discussed below, and in White Paper 8, “Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River”, it is expected that recovery would be rapid.

For the active remediation alternatives (C1, C2, D, E and F), there is the potential transient impact from the temporary exposure of deeper, more highly contaminated sediments during excavation activities. This impact would be minimized by the quick completion of removal activities, and (if needed) placement of a post-dredging sand cover as soon as practicable after the removal operations are complete.

**Implementability**

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility and coordination with other governmental entities are also considered.

Technical Feasibility
Both the No Action and MNR alternatives are technically feasible because no active measures other than continued sampling would be taken. Technical feasibility for the active remediation alternatives is discussed below in terms of the main components of the alternatives. Additional information is provided in the FS.

**Sediment Processing/Transfer Facilities.** Alternatives C1, C2, D, E and F require sediment processing/transfer facilities. At these facilities, the transfer, dewatering and stabilization of dredged material would be conducted. Each of these activities is considered a readily implementable, commonly engineered activity. Design of sediment processing/transfer facilities will include requirements for the control of light, noise, air emissions, and water discharges.

WDNR and EPA have not determined the location of the sediment processing/transfer facilities. Preliminary criteria were utilized to establish a list of preliminary candidate sites to allow for the preparation of a cost estimate. In preparing the cost estimate in the Feasibility Study, WDNR and EPA assumed upland staging area in the vicinity of Arrowhead Park, at the southern end of Little Lake Butte des Morts. This facility (wherever located) would be temporary and removed after completion of the active remedial activities.

**Removal.** Alternatives C1, C2, D, E, and F require the dredging of contaminated sediments. Dredging of sediments is a readily implementable and environmentally effective engineering activity. Two concerns are relevant to whether sediments can be dredged effectively: 1) resuspension and releases during dredging and, 2) resulting residual contaminant concentrations that may remain in sediments after dredging is completed. Regarding resuspension, as discussed above environmental dredges have been shown to generally not release significant quantities of contaminants during removal operations. The type of dredging equipment (mechanical and/or hydraulic) will be selected during the remedial design, using the most appropriate equipment for the specific conditions in the River. The use of silt screens or other barriers, as appropriate, could further assist in limiting downstream migration of PCBs and may be used as well. Regarding post-dredging residual contaminant concentrations comparable projects indicate that achieving the 1 ppm Action Level in remaining sediments is readily achievable. The Fox River SMU 56/57 dredging project achieved a 96 percent reduction in the average concentration of contaminated sediments targeted for removal in that project. This is consistent with results for other dredging projects having similar site conditions (see Appendix B of the FS, and Hudson River White Paper ID 312663, “Post-Dredging PCB Residuals).

**Dewatering.** Alternatives C1, C2, D, E and F would require removal of excess water from dredged sediments. Either mechanical or passive dewatering would be used for this purpose. These are conventional, commonly utilized proven technologies, and are readily implementable and effective.

**Water Treatment.** Conventional water treatment technologies for dredge water have been proven commonly reliable, and are readily implementable and effective.

**Capping.** Alternative F includes some capping of areas that meet the criteria for areas that are acceptable for capping. The placement of capping materials is a readily implementable engineering activity. Sand, gravel and/or fine materials may be utilized for capping. Clean sand could be placed over contaminated deposits to give a surficial concentration in the capped areas that is essentially without contamination. The type (e.g., texture/size and sorting) of cap material will be determined on a location specific basis.

**Post-Dredging Sand Cover.** The selected alternative envisions an option of limited backfilling if required. The placement of backfill is a readily implementable engineering activity. Sand or other materials, as appropriate may be utilized for backfill.

**Transportation.** Dredged materials may be transported in-river to sediment processing / transfer facilities using barges or pipelines. These are considered readily implementable engineering activities. Transportation via pipeline is limited to certain distances because of pumping and right-of-way limitations. Consequently, in some areas of the River, pipelines may not be implementable.

Off-site transportation of dredged materials to disposal facilities will be by truck, rail and/or barge. These forms of transportation are routine engineering activities that have been employed at many Superfund sites and are technically implementable. WDNR and EPA will comply with all legal regulatory requirements for transporting both hazardous and non-hazardous wastes.

**Disposal.** Off-site disposal is a common activity at many Superfund sites. The number and location of off-site disposal facilities will be based on dredged material volume, transportation and cost considerations. It is expected that appropriate disposal will be in the Fox Valley area.

Alternatives C1, C2 and F all include disposal options. Alternative D uses an in-water confined disposal facility for disposal. These are conventional technologies and readily implementable. Under Alternative F, approximately 20 percent of the sediments will be capped in-situ (see Table 23, above). For the areas that will be capped, it is considered technically achievable. It should be noted that certain areas are not amenable to capping and are thus “off limits” for capping. This is because these areas fail to meet certain criteria for capping (e.g., sufficient water depth).

An ex-situ treatment alternative (Alternative E), vitrification, was determined to be technically feasible. This does require reuse of residual materials after treatment.

**Treatment.** Alternative E includes thermal treatment by vitrification, and is technically implementable to meet cleanup goals.

<u>Administrative Feasibility</u>
Both No Action and MNR require no active measures. All alternatives, except No Action include an administrative requirement for fish consumption advisories. Since fish consumption advisories are already in place, this alternative requirement is already met and would continue even under the No Action alternative. The active remedial measures are somewhat more difficult to implement from an administrative feasibility perspective due to the need for siting the sediment processing/transfer facilities and addressing the associated real property issues, and the need to make arrangements to utilize the River with minimal interruption of boat traffic.

**Sediment Processing/Transfer Facilities.** For the active remediation alternatives (Alternatives C1, C2, D, E and F), the transfer facilities, constructed on land adjacent to the River, or in-river, are considered “on-site” for the purposes of the permit exemption under CERCLA Section 121(e), although any such facilities will comply with the substantive requirements of any otherwise necessary Federal or State permits.

**Removal.** Operations under these alternatives will have to be performed in conformance with the substantive requirements of regulatory programs implemented by the U.S. Army Corps of Engineers under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. In addition, discharges during remediation will conform to Wisconsin Statutes and substantive WDNR regulations related to dredging and maintaining water quality.

**Disposal.** Identifying a local landfill for disposal of sediments dredged from Little Lake Butte des Morts is feasible. This would have to be coordinated with local authorities, consistent with appropriate ARARs.

**Capping and CDF.** For Alternative D and F, a lake bed grant would likely be required from the Wisconsin legislature to construct a cap or in-water CDF. If riparian rights exist, agreements with landowners with riparian rights would be required. These considerations would be addressed during design.

**Treatment.** Alternative E is administratively feasible. Air emissions permits would be required if sediments are treated off-site.

**Availability of Services and Materials.** For the No Action and MNR alternatives, all needed services and materials are available. For the active remediation alternatives (Alternatives C1, C2, D, E and F), equipment and personnel related to dredging and materials handling (e.g., sediment dewatering) are commercially available. Technology and associated goods and services for capping or a post-dredging sand cover, upland landfill or CDF construction are locally available.

Cost

Cost includes estimated capital and annual operation and maintenance costs, as well as total capitol cost. Present worth cost is the total capital cost and operation and maintenance costs of an alternative over time in today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent. (This is a standard assumption in accordance with EPA CERCLA guidance.)

The net present worth of the remedial alternatives range from $4.5 million for No Action to $116.7 million for Alternative C1. For the active remedial alternatives, the present worth of the capital and present worth of operation and maintenance costs which range from approximately $63.6 million for Alternative E to $116.7 million for Alternative C1. Capital costs, present worth of operation and maintenance costs, and the total costs are listed in Table 24, below.

**Table 24 Comparison of Present Worth Costs for OU 1 Alternatives at the 1 ppm RAL**

| | Estimated Volume Removed or Contaminated (cubic yards) | Estimated PCB Mass Remediated (pounds) | Capital Costs ($ millions) | O&M Cost ($ millions) | Present Worth Total Cost ($ Millions) |
|---|---|---|---|---|---|
| A – No Action | 0 | 0 | 0 | 4.5 | 4.5 |
| B – Monitored Natural Recovery | 0 | 0 | 0 | 9.9 | 9.9 |
| C1 – Dredging/passive dewatering/off-site disposal | 784,000 | 3770 | 112.2 | 4.5 | 116.7 |
| C2 – Dredging/mechanical dewatering/off-site disposal | 784,000 | 3770 | 61.7 | 4.5 | 66.2 |
| D – Dredge to a Confined Disposal Facility | 784,000 | 3770 | 63.5 | 4.5 | 68.0 |
| E – Dredge and Vitrification | 784,000 | 3770 | 59.1 | 4.5 | 63.6 |
| F – Dredging and Capping to Maximum extent practicable | 635,500 | 3770 | 86.0 | 4.5 | 90.5 |

*From Section 7 and Appendix H of the FS.*

### 11.1.3 Agency and Community Criteria for Operable Unit

Agency Acceptance
The State of Wisconsin has been actively involved in managing the resources of the Lower Fox River since before there was a federal Superfund law. These efforts have led to significant state knowledge and understanding of the River and Bay and of the contamination problems within those areas. As a result of this expertise, WDNR has served as the lead agency responsible for assessing risks and conducting the RI/FS, which forms the basis for the Proposed Plan and Record of Decision (ROD). As the lead agency, WDNR has worked closely with EPA to cooperatively develop this ROD. Both WDNR and EPA support the selection of this remedy as is evidenced by the joint issuance of this ROD by both WDNR and EPA.

Community Acceptance
Community Acceptance considers whether the local community agrees with EPA's analyses and preferred alternative. Comments received on the Proposed Plan are an important indicator of community acceptance. Community acceptance of the Proposed Plan was evaluated based on comments received at the public meetings and during the public comment period. There were more than 4800 comments concerning the Proposed Plan. This ROD includes a responsiveness summary, Appendix B, which addresses public comments.

## 11.2 Operable Unit 2 (Appleton to Little Rapids)

Table 25 below summarizes the comparative analysis for OU 2 alternatives and how each alternative meets, or does not meet requirements for each of the nine criteria, described above.

A detailed comparative analysis for four of the nine criteria, Protection of Human Health and the Environment, Long-term Effectiveness and Permanence, Implementability and Cost are discussed below for all alternatives. A comparison for five of the nine criteria (Compliance with Applicable or Relevant and Appropriate Requirements, Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment, Short-term Effectiveness, Agency Acceptance and Community Acceptance) is substantially the same as Alternatives discussed in OU 1 and are therefore not repeated. Similar to the OU 1, Alternatives C and E for OU 2 are also considered “Active Remediation Alternatives.”

The major differences between OU 1 and OU 2 that relate to this comparative analysis of alternatives are the following:

1) Mass of PCB contaminants in OU 2 is relatively small and potential for downstream release proportionally less, and result in a relatively faster time to recovery,
2) Bedrock immediately underlies contaminated sediment in the upper portion of the OU 2, where most of the deposits are located; this makes complete removal of contaminated materials impracticable,
3) Locks, dams, and the urban/residential setting of a considerable portion of OU 2 make access more difficult than in OU 1.

**Table 25 Operable Unit 2. Appleton to Little Rapids Alternatives**

| | | **Selected Alternative** | | |
|---|---|---|---|---|
| Yes = Fully meets criteria<br>Partial = Partially meets criteria<br>No = Does not meet criteria | Alternative A<br>No Action | Alternative B<br>Monitored Natural Recovery | Alternative C<br>Dredge with off site disposal | Alternative E<br>Dredge and Virtification |
| 1. Overall protection of human health and the environment | No | Partial | Partial | Partial |
| 2. Compliance with Applicable or Relevant & Appropriate Requirements | No | Partial | Yes | Partial |
| 3. Long-term Effectiveness and Permanence | No | Partial | Yes | Yes |
| 4. Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment | No | No | Yes | Yes |
| 5. Short-term Effectiveness | No | Partial | Partial | Partial |
| 6. Implementability | Yes | Yes | Partial | Partial |
| 7. Cost (millions of $) | $ 4.5 | $ 9.9 | $ 16.5 to 38.3 | $ 15.2 to 26.2 |
| 8. Agency Acceptance | The WDNR has been the lead agency in developing the RI/FS and the ROD. Both WDNR and EPA support the selected alternative of Monitored Natural Recovery for this OU. | | | |
| 9. Community Acceptance | The level of community acceptance of the selected alternative is outlined in the Responsiveness Summary. | | | |

## 11.2.1 Threshold Criteria for Operable Unit 2

**Protection of Human Health and the Environment**

The primary risk to human health associated with the contaminated sediment is consumption of fish. The primary risk to the environment is the bioaccumulation of PCBs from the consumption of fish or, for invertebrates, the direct ingestion/consumption of sediment. Similar to the evaluation for OU 1, protection of human health and the environment was evaluated using five lines of evidence:

- Residual PCB concentrations in surficial sediment using surface-weighted averaging after completion of a remedy;
- Average PCB concentrations in surface water,
- The projected number of years required to reach safe consumption of fish;
- The projected number of years required to reach a surface sediment concentration protective of fish or other biota, and
- PCB loadings to downstream areas and total mass contained or removed.

These are discussed below.

Residual PCB concentrations in surficial sediment and surface water

Alternatives C and E for OU 2 could achieve greater reductions in average concentration of contaminants in surficial sediment and in surface water relative to the No Action and MNR Alternatives (Alternatives A and B, respectively) – see Table 26 below. Alternatives C and E produce a reduction in residual PCB concentrations in surface sediment using surface-weighted averaging after completion, when compared to the No Action or MNR Alternatives. The estimated surface water concentrations 30-years after remediation is reduced 93 percent for Alternatives C or E relative to No Action and Monitored Natural Recovery (i.e., 0.19 ng/L versus 2.76 ng/L in Table 26, below). It should be noted that these estimates do not take into account the already completed removal of Deposit N that occurred during 1998-1999. Deposit N comprised 32 percent of the mass (i.e., 65 pounds) of PCBs in OU 2. More recent calculation estimated the average SWAC for OU 2 is 0.61 ppm with the PCB mass from Deposit N and O removed.

**Table 26 Post-Remediation Sediment and Surface Water Concentrations in OU 2**

| Alternative | Average PCB Concentrations in Surficial Sediments (ppm) | Estimated Surface Water Concentrations 30-years after Remediation (ng/L)[3] |
|---|---|---|
| A, B | 0.61[1] | 2.76 |
| C, E | 0.066[2] | 0.19 |

*1. Value is from November 14, 2002 email from RETEC to WDNR on SWAC values in OUs 1 – 4*
*2. Value is from FS Tables 5-4*
*3. Values are from Table 8-5 B*

Time to Reach Acceptable Fish Tissue Concentrations

Reductions in the time required to reach levels safe for human consumption of fish after implementation of Alternatives C and E relative to the No Action and Monitored Natural Recovery (MNR) alternatives are listed in Table 27 below. Recovery times for other human health receptors are presented in the FS, Chapter 8, Table 8-7. Again, these calculations do not consider the removal of Deposit N, completed by WDNR during 1998-1999.

**Table 27 Time to Achieve Acceptable Fish Tissue Concentrations for Walleye in OU 2 at 1 ppm**

| Fish | Receptor | Risk Level Goal | Estimated Years to Achieve | |
|---|---|---|---|---|
| | | | Alternatives C, E | Alternatives A, B |
| Walleye | Recreational Angler | RME Hazard Index of 1.0 | 4* | 40 |
| Walleye | High Intake Fish Consumer | RME Hazard Index of 1.0 | 7* | 55 |
| Walleye | Recreational Angler | RME $10^{-5}$ cancer risk level | 70* | 42 |
| Walleye | High Intake Fish Consumer | RME $10^{-5}$ cancer risk level | 89* | 65 |

** Does not consider removal of Deposit N.*
*Data is from FS Table 8-14.*

Time to Surface Sediment Concentration Protective of Fish or Other Biota

Alternatives C and E would achieve rreductions in the time required to reach protective levels for ecological receptors, relative to the No Action and MNR alternatives. For representative receptors, implementation of active remediation alternatives results in time reduction relative to

No Action or MNR as is shown in Table 28, below. Recovery times for additional ecological receptors and recovery times are presented in the FS, Chapter 8, Table 8-7. These calculations do not consider removal of Deposit N that occurred during 1998-1999.

**Table 28 Time to Protective Levels in Sediments for Representative Ecological Receptors in OU 2**

| Fish | Receptor | Risk Level Goal | Estimated years to achieve | |
|---|---|---|---|---|
| | | | Alternatives C, E | Alternatives A, B |
| Carp | Carnivorous bird | NOAEC | 17* | 71 |
| Carp | Piscivorous mammal | NOAEC | 34* | 100 |
| Sediment | Sediment invertebrate | TEL | 28* | 81 |

** Does not consider removal of Deposit N.*
*Data is from FS Table 8-16.*

<u>PCB loadings to downstream areas and total mass contained or removed</u>
Reduction of the PCB load transported over the Little Rapids Dam into the downstream areas of the Fox River is a measure of the overall protection of human health and the environment. Reduced PCB loading from OU 2 will ultimately contribute to reduction of concentrations of PCBs in sediment, water and fish, and thereby reduce risk to humans and ecological receptors in the Fox River. Alternatives C or E provide for improvement relative to No Action and MNR.

<u>Summary</u>
No Action and MNR may take 40 to 70 years to reach acceptable fish tissue concentrations for recreational anglers and may take more than 80 years to reach safe ecological levels for carp. Surface water WQS will not be met in 100 years. However, the recovery times may be overestimated, as these estimates do not consider the removal of Deposit N, which occurred during 1998-1999. Finally, although Alternatives C or E provide a more protective remedy than the No Action and MNR alternatives, risks would only be moderately reduced.

The comparative analysis for compliance with Applicable or Relevant and Appropriate Requirements is substantially the same as discussed for the OU 1 evaluation and is not repeated.

### 11.2.2 Balancing Criteria for Operable Unit 2

**Long-term Effectiveness and Permanence**

<u>Reduction of Residual Risk</u>
The No Action and MNR alternatives result in a continuation of the degraded condition of the sediments and surface water quality of OU 2, for at least several decades. Nevertheless, modeling demonstrates that OU 2 will eventually recover, due to slow natural decreases in PCB concentrations, primarily due to burial and dilution.

Alternatives C and E would reduce residual risk through removal of 46,200 cubic yards of sediments containing approximately 92 kg (about 200 pounds) of PCBs over an area of 34 acres at the 1 ppm RAL for OU 1. This does result in a reduction in time required to reach safe human fish consumption rates when compared to the No Action and MNR Alternatives. However, based on results already achieved at the Deposit N project with conditions representative of those present in the remainder of OU 2 (bedrock underlying contaminated sediments), it may not be possible to consistently meet the RAL of 1 ppm. The Deposit N pilot project demonstrated that a significant percentage of PCB contaminated sediment could be removed, although it did not nor was it designed to, demonstrate that a consistent reduction in contaminant concentration in residual sediments was feasible. This is especially true for the portions of OU 2 where there is bedrock underlying contaminated sediments.

Reliability of Controls

For Alternatives C and E, No Action and MNR, fish consumption advisories and fishing restrictions can provide limited protection to humans until PCB concentrations in fish are reduced to the point where the fish consumption advisories and fishing restrictions can be relaxed or discontinued entirely.

Alternatives C and E permanently remove contaminated sediment from the River, and can achieve risk reduction as well as reduce the potential of releases by scour of PCB-contaminated sediments. Alternatives C and E utilize established technologies and are considered in part to be sufficiently reliable. As discussed below, dredging does not work well with bedrock underlying shallow sediment deposits (as is present for most of the sediment deposits in OU 2).

Summary

Based on the above analysis of reduction in residual risk and adequacy and reliability of controls, Alternatives C and E are marginally better than the No Action and MNR alternatives but are likely to have difficulty in consistently achieving the 1 ppm RAL.

**Implementability**

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility and coordination with other governmental entities are also considered.

Both the No Action and MNR alternatives are technically feasible, as no active measures would be taken for the PCB-contaminated sediments.

Technical feasibility for the active remediation alternatives is discussed below for operational aspects of the alternatives that differ from OU 1.

**Sediment Processing/Transfer Facilities** – WDNR and EPA have not determined the location of the sediment processing/transfer facilities for Alternatives C and E. Preliminary criteria were utilized to establish a list of preliminary candidate sites to allow for the preparation of a cost estimate. This analysis indicates that several access locations would be required due to navigation impediments by numerous dams and locks between the Appleton dam and Little Rapids dam. For cost purposes, access locations were assumed in Kimberly, near Wrightstown and near the Little Rapids dam. Due to the number of access locations required and the physical barriers presented by the many locks and dams in this Operable Unit, access limitations would make implementation more difficult or could require modifications to conventional dredging technologies.

**Removal** - Alternatives C and E require the dredging of contaminated sediments. For the majority of OU 2, bedrock underlying contaminated sediments may make complete removal of contaminated sediment and achieving the Action Level objective of 1 ppm impracticable. Additionally, due to higher water velocities for this Operable Unit, a post-dredging sand cover would likely not be effective in reliably covering post-dredging high concentrations of residual PCBs due to the greater water velocities.

Summary
Alternatives C and E may be difficult to effectively implement due to site conditions with bedrock underlying contaminated sediments, and the large number of locks and dams which would limit river access and navigation. Administrative implementability would be consistent with OU 1.

Cost
Cost includes estimated capital and annual operation and maintenance costs, as well as total capitol cost. Present worth cost is the total capital cost and operation and maintenance costs of an alternative over time in today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent. (This is a standard assumption in accordance with EPA CERCLA guidance.)

The net present worth of the remedial alternatives range from $4.5 million for No Action to $20.1 million for Alternative C (see Table 29, below).

The comparative analysis for Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment, and Short-term Effectiveness is substantially the same as for the OU 1 evaluation and are not repeated.

### 11.2.3 Agency and Community Criteria for Operable Unit 2

The comparative analysis for Agency Acceptance and Community Acceptance is substantially the same as discussed for the OU 1 evaluation and is not repeated.

**Table 29 Comparison of Present Worth Costs for OU 2 Alternatives at a 1 ppm RAL**

| | Estimated Volume Removed or contained (cubic yards) | Estimated PCB Mass Remediated (pounds) | Capital Costs ($ millions) | O&M Cost ($ millions) | Present-Worth Total Cost ($ millions) |
|---|---|---|---|---|---|
| A – No Action | 0 | 0 | 0 | 4.5 | 4.5 |
| B – Monitored Natural Recovery | 0 | 0 | 0 | 9.9 | 9.9 |
| C – Dredging/passive dewatering/off-site disposal | 46,200 | 200 | 33.8 | 4.5 | 20.1 |
| E – Dredge and Vitrification | 46,200 | 200 | 21.7 | 4.5 | 17.1 |

*From Section 7 and Appendix H of the FS.*

## 12. PRINCIPAL THREAT WASTES

The National Contingency Plan (NCP) establishes an expectation that treatment will be used to address the principal threats at a site whenever practical. Engineering controls, such as on-site or off-site containment, may be used for wastes that pose a relatively low long-term threat or where treatment is impractical (NCP Section 300.430(a)(1)(iii) and Superfund Publication 9380.3-06FS, November 1991 “A Guide to Principal Threat and Low Level Threat Wastes”).

The concept of principal threat and low-level threat wastes is applied on a site-specific basis when characterizing source material. Source material is defined as material that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, to surface water, to air, or acts as a source for direct exposure. In the Lower Fox River and Green Bay Site, the contaminated sediment are source materials.

Principal threat wastes are those source materials considered to be highly toxic or highly mobile which cannot be reliably contained or that would present a significant risk to human health or the environment should exposure occur. The manner in which principal threats are addressed generally will determine whether the statutory preference for treatment as a principal element is satisfied. Although USEPA has not established a threshold level of toxicity/risk to identify a principal threat waste, generally where toxicity and mobility of source material combine to pose a potential risk of $10^{-3}$ or greater the source material is considered principal threat waste.

With respect to the Fox River sediments in OU 1, some PCB concentrations create a risk in the range of $10^{-3}$ or more. The preference for treatment outlined above applies to these particular sediments. However, it would be impracticable to closely identify, isolate and treat these principal threat wastes differently than the other PCB sediments in OU 1. The dredging technology that will be employed to accomplish the OU 1 remedy does not distinguish among gradations of contamination in source materials. Nevertheless, at the conclusion of the OU 1 remedy the source materials (and principal threat wastes) will have been removed from the River, dewatered, and deposited in a landfill. In so doing the mobility of the principal threat wastes will have been greatly reduced.

# 13. SELECTED REMEDY

## 13.1 The Selected Remedy

The selected remedy for OU 1 is alternative C2. This remedy includes removal, dewatering, and off-site disposal of an estimated 784,200 cubic yards of PCB-contaminated sediment from OU 1 (Little Lake Butte des Morts) with PCB concentrations greater than 1 ppm. These sediments are estimated to contain approximately 1,715 kg (about 3,770lbs) of PCBs, or approximately 90 percent of the total PCB mass in OU 1.

The selected remedy for OU 2 is Alternative B, Monitored Natural Recovery and Institutional Controls.

<u>Summary and Description of the Rationale for the Selected Remedy</u>

The summary of the rationale for the selected remedy will be addressed for each Operable Unit. The following sections discuss specifics of how the selected alternative would be implemented at each OU. Five-year reviews will be conducted of remedial activities at each OU to determine remedy effectiveness.

**Operable Unit 1 – Little Lake Butte des Morts, Alternative C2 -** Alternative C2 includes the removal of sediment with PCB concentrations greater than the 1.0 ppm remedial action level (RAL) using an environmental dredge, followed by dewatering and off-site disposal of the sediment. The total volume of sediment to be dredged in this alternative is approximately 784,200 cy.

- **Site Mobilization and Preparation.** The staging area for this OU will be determined during the design stage. Site preparation at the staging area will include collecting soil samples, securing the onshore property area for equipment staging, and constructing the mechanical sediment dewatering facility, water treatment facilities, and sediment storage and truck loading areas. A docking facility for dredging may need to be constructed. Assuming a staging area can be found south of the railroad bridge, a separate staging area for the dredge when operating north of the railroad bridge may be needed. This facility would be used solely for the purpose of docking dredging equipment—any dredge slurry will be pumped to southern staging area.

- **Sediment Removal.** Sediment removal will be conducted using a dredge (e.g., cutterhead or horizontal auger or other method). Given the volumes and operating assumptions described in the FS, completing the removal effort is estimated to take approximately six years for OU 1. For a dredging removal, in-water pipelines will carry the slurry from the dredging area to the staging area for dewatering. For longer pipeline runs, it would be necessary to utilize in-line booster pumps to pump the slurry to the dewatering facility. If necessary, silt curtains around the dredging area may be used to minimize sediment resuspension downstream of the dredging operation. Buoys and other waterway markers will be installed around the perimeter of the work area. Other activities associated with sediment removal will be water quality monitoring, post-removal sediment surveys, and site restoration.
- **Sediment Dewatering.** Removal using dredging technologies will require mechanical dewatering requiring land purchase or access, site clearing, and possibly construction of temporary holding ponds. Dewatering techniques would likely be similar to the mechanical processes used for both Lower Fox River demonstration projects, including a series of shaker screens, hydrocyclones, and belt filter presses.
- **Water Treatment.** Water treatment will require the purchase of equipment and materials for flocculation, clarification, and sand filtration. Water treatment will be conducted 24 hours per day, 7 days per week during the dredging season. Discharge water for hydraulic dredging is estimated at 570,000 gallons per day. Daily discharge water quality monitoring is included in the cost estimate. Treated water will be sampled and analyzed to verify compliance with the appropriate discharge requirements. Carbon filtration will likely be necessary.
- **Sediment Disposal.** Sediment disposal includes the loading and transportation of the sediment to an NR 500 landfill with TSCA approval (needed for sediment if concentrations are over 50 mg/kg PCB) after mechanical dewatering. The sediment will be loaded using a front-end loader into tractor-trailer end dumps fitted with bed liners or sealed gates. Each load will be manifested and weighed. The haul trucks will pass through a wheel wash prior to leaving the staging area to prevent the tracking of soil onto nearby streets and highways.
- **Demobilization and Site Restoration.** Demobilization and site restoration will involve removing all equipment from the staging and work areas and restoring the site to, at a minimum, its original condition.
- **Institutional Controls and Monitoring.** Baseline monitoring will include pre- and post-remedial sampling of water, sediment, and biological tissue. Monitoring during implementation will include air and surface water sampling. Verification monitoring to confirm that PCB contamination has been removed to the RAL may include surface and subsurface sediment sampling. Long-term monitoring will include surface water, biological tissue, and possibly surface sediment sampling. The types and frequency of pre-construction monitoring will be developed during remedial design. Plans for monitoring during and after construction will be developed during the remedial design and modified during and after construction as appropriate. Institutional controls may include access restrictions, land use or water use restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas.

- **Achievement of Remedial Action Level Objective.** The mass and volume to be remediated will be based on setting a dredge elevation based on a RAL of 1 ppm while achieving a SWAC of 0.25 ppm for OU 1. The success of the selected remedy for OU 1 will be evaluated based on a SWAC of 0.25 ppm with samples taken from 0-10 cm depth. This is discussed further in section 13.3.

**Operable Unit 2 – Appleton to Little Rapids, Alternative B -** The MNR alternative will include a 40-year monitoring program as is discussed in the FS for measuring PCB and mercury levels in water, sediment, invertebrates, fish, and birds. The monitoring program will be developed to effectively measure achievement of and progress toward the RAOs. In summary, the monitoring program will include:

- Surface water quality sampling to determine the downstream transport of PCB mass into Green Bay;
- Fish and waterfowl tissue sampling to determine the residual risk of PCB and mercury consumption to human receptors;
- Fish, bird, and zebra mussel tissue sampling to determine the residual risk of PCB uptake to environmental receptors;
- Population studies of bald eagles and double-crested cormorants to assess the residual effects of PCBs and mercury on reproductive viability; and
- Possible surface sediment sampling in MNR areas to assess potential recontamination from upstream sources and the status of natural recovery.

The types and frequency of pre-construction monitoring will be developed during MNR long term monitoring plan design. Plans for monitoring will be developed during the remedial design and modified during and after the upstream construction in OU 1, as appropriate.

Until the RAOs have been achieved, existing institutional controls will have to be maintained to help prevent exposure of human receptors to contaminants. Institutional controls may include access restrictions, land use or water use restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas. Deposit DD, an area in OU 2 of greater contamination, will be addressed as part of the active remediation at adjacent OU 3.

## 13.2 Summary of the Estimated Costs of the Selected Remedy

The total estimated present-worth cost of the selected remedy is $76.1 million. This is an engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost (based on year 2001 dollars). Changes in the cost elements are likely to occur as a result of new information and data collected during the remedial design. Major changes may be documented in a memorandum in the administrative record, an Explanation of Significant Difference (ESD), or a ROD amendment.

## 13.3 Cleanup Standards and Outcomes for the Selected Remedy

The selection of a remedy was accomplished through the evaluation of the nine criteria as specified in the NCP. A remedy selected for a site must be protective of human health and the environment, comply with ARARs (or justify a waiver) and offer the best balance of tradeoffs with respect to the balancing and modifying criteria in the NCP.

Through the analyses conducted for the RI/FS, WDNR and EPA have determined that there is an unacceptable risk to human health and the environment from the consumption of fish from the Fox River. It has also been determined that the unacceptable risk will continue for many decades without active remediation of the PCB-contaminated sediments in OU 1.

### 13.3.1 Achieving Cleanup Standards

WDNR and EPA believe the removal of sediments with PCB concentrations greater than the 1.0 ppm RAL in OU 1 is important to achieving the timely reduction of risks to an acceptable level. WDNR and EPA envision that all sediment contaminated at concentrations above the RAL in OU 1 will be removed. Therefore, this ROD provides that under certain circumstances a sand cover may be used to supplement the primary dredging remedy in order to reach the risk reduction targets. Pre-remediation sampling and characterization efforts will define a spatial “footprint” (both horizontally and vertically) of the sediment in OU 1 that has a concentration of PCBs greater than 1 ppm. It is this footprint that is targeted for removal by dredging. If dredging is able to achieve this result (i.e., remove all sediments with PCB concentrations greater than 1 ppm), the active remediation portion of the OU 1 remedy will be complete.

However, if after dredging is completed for OU 1, sampling shows that the 1 ppm RAL has not been achieved, a SWAC of 0.25 ppm may be used to assess the effectiveness of PCB removal. If that SWAC of 0.25 ppm has not been achieved for OU 1, then the remedy provides certain options to further reduce risk. The first option is that additional dredging may be undertaken to ensure that all sediments with PCB concentrations greater than the 1 ppm RAL are removed throughout the particular deposit. A second option would be to place a sand cover on dredged areas to reduce surficial concentrations such that a SWAC of 0.25 ppm for OU 1 is achieved.

**Explanation of Remedial Action Level, Surface Weighted Average Concentration and Sediment Quality Threshold.**

*The term Remedial Action Level (“RAL”) refers to a PCB concentration in sediment used to define an area or volume of contaminated sediment that is targeted for remediation. In other words, this ROD calls for the removal by dredging of all sediment in OU 1 that has a PCB concentration of greater than1 ppm. If all sediment with a concentration greater than the 1 ppm RAL is removed, then it is expected that the residual Surface Weighted Average Concentration (“SWAC”) of sediment will be 0.19 ppm in OU 1. The SWAC in this instance is less than the RAL because the SWAC is calculated as an average concentration over the entire OU 1, after the removal of sediment from discrete areas (“deposits”) which are above the RAL and includes averaging over areas in which there are surface concentrations less that the RAL. SWAC calculations are discussed in section 5 of the FS.*

*The term “Sediment Quality Threshold” (SQT) refers to the PCB concentration in the sediment that is protective of specified human and ecological receptors. SQTs vary depending on the sensitivity of the particular receptor (e.g., recreational anglers, “high intake” fish consumers, walleye, mink, etc.). Put another way, if the remediation called for in this ROD results in a sediment concentration at or below the SQT, then the risk to specified human and ecological receptors will have been reduced to a safe level. It is important to understand that immediately upon the completion of the dredging, it is not expected that the SQT will be achieved. Instead, it is contemplated that the SQT will be met only after the river is allowed a certain amount of time to “recover” through natural processes following active dredging.*

### 13.3.2 Expected Outcomes of Selected Remedy and RAL Rationale

RAOs were developed to provide relative comparisons for different remedial alternatives. RAO 1 relates to achieving surface water quality standards. RAOs 2 and 3 relate to protectiveness for human and ecological receptors. RAO 4 evaluates long-term relative releases to Green

Bay and Lake Michigan, and RAO 5 considers short term releases from potential remedies themselves.

RAO 1 may not be achieved in the foreseeable future due to the very stringent goals for PCBs acceptable in surface waters, but nevertheless significant risk reduction will occur (Table 13). Recovery times estimated for RAOs 2 (i.e., protection of human health) and 3 (i.e., protection of ecological receptors) indicate that they will be met well within the defined goals. RAO4 relates to loading of Green Bay and Lake Michigan and indirectly relate to OUs 1 and 2. However, reductions of loadings from removal of contaminants in OU 1 will significantly reduce contaminant migration downstream and will therefore contribute to achieving RAO4. RAO5 is achievable with conventional removal environmental removal technologies for OU 1 and does not apply to OU 2.

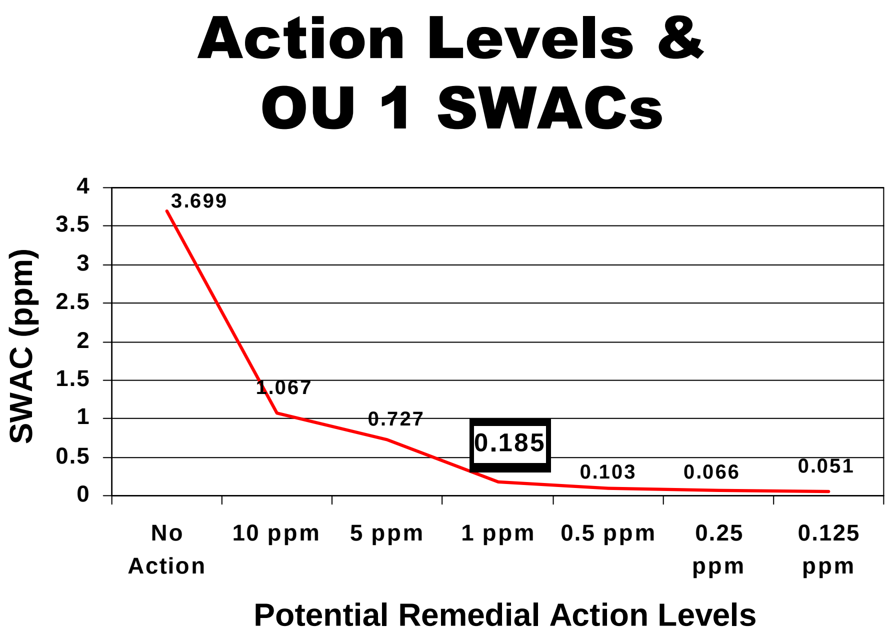
RAOs 2 and 3 are evaluated in the alternative-specific Risk Assessment in the FS by estimating the time required to reach the protectiveness criteria for human health (i.e., removal of fish advisories) and the time required to reach the protectiveness criteria for ecological receptors for no removal and for different remedial action levels for contaminant removal.

A PCB concentration of 1 ppm has been selected as the appropriate Remedial Action Level based on the its ability to achieve Remedial Action Objectives (RAOs) in surface water and for human health and ecological receptors within a reasonable timeframe relative to the anticipated costs. Exposures to PCB sediment concentrations above 1 ppm must be eliminated in order to achieve a protective Surface Weighted Average Concentration (SWAC) within a reasonable timeframe. This RAL will also reduce and minimize surface water concentrations and the release of contaminants to downstream areas of the Fox River. Studies conducted as part of the Lower Fox River and Green Bay RI/FS indicate that a 1 ppm RAL shows the greatest decrease in projected surface water concentrations relative to the other action levels.

PCB RALs of No Action, 5.0 ppm, 0.5 ppm, 0.25 ppm, and 0.125 ppm were also evaluated. However, those RALs greater than 1 ppm would require a significant amount of additional time to achieve the RAOs for the Site. For those RALs less than 1 ppm: the RAOs would not necessarily be achieved sooner than the 1 ppm RAL. The RAOs considered in determination of the RAL are discussed below for Operable Units 1 and 2. It is important to note that the absolute numbers have uncertainty inherent with model predictions, however relative differences among the RALs are reliable

<u>Justification for Operable Unit 1 Remedial Action Level of 1.0 ppm</u>
Figure 5 shows our modeling analysis of sediment RALs in comparison with the Surface Weighted Average Concentrations (SWACs) which will result from the cleanup at the selected 1 ppm RAL. Modeling suggests that a 1 ppm RAL can achieve an estimated 0.185 ppm PCB SWAC for OU 1 (Figure 5 below). Selecting a sediment RAL of 1 ppm clearly stands out as the most effective RAL because the risk declines significantly in a reasonable time period (see figures 6 and figure 7). This will result in reaching risk reductions in the years estimated in Table 30, below.

**Figure 5 Remedial Action Levels and Estimated SWACs for Evaluated RALs for OU 1 (from FS Table 5-4)**



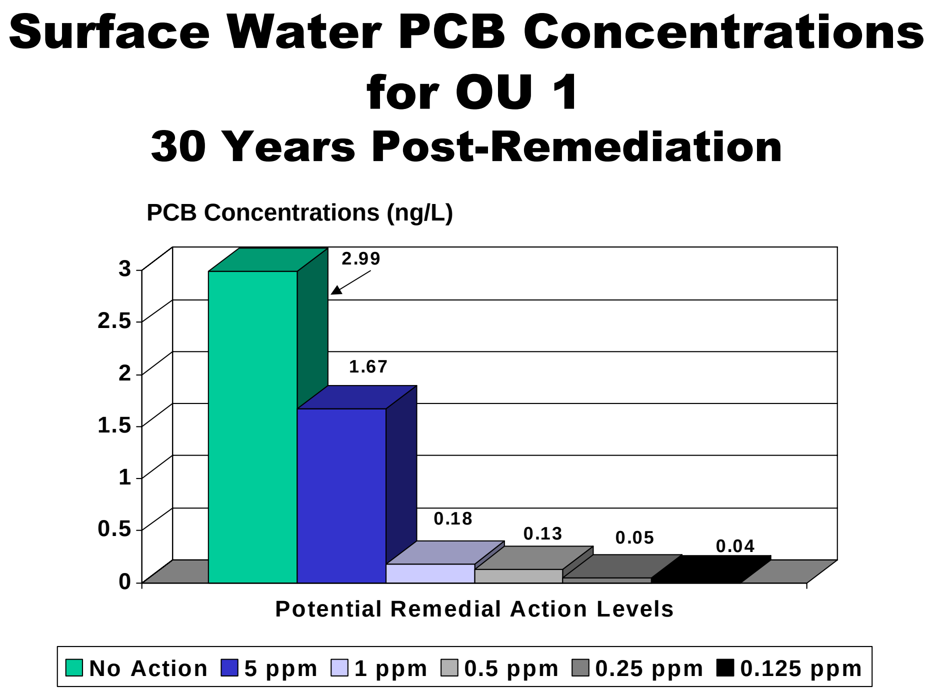

As shown in Table 30 below, modeling suggests that a sediment RAL of 1.0 ppm, and a SWAC of 0.185 ppm will lead to fairly rapid declines in PCB fish tissue concentrations. Using the 1 ppm RAL, Table 30 projects the number of years until the risk of fish ingestion/consumption declines to acceptable levels for different consumers.

**Table 30 Estimated Years to Reach Human Health and Ecological Thresholds to Achieve Risk Reduction for the Operable Unit 1 at a RAL of 1 ppm**

| Fish | Receptor | Risk Level Goal | Estimated Years |
|---|---|---|---|
| Walleye | Recreational Angler | RME Hazard Index of 1.0 | <1 |
| Walleye | High Intake Fish Consumer | RME Hazard Index of 1.0 | 4 |
| Walleye | Recreational Angler | RME $10^{-5}$ cancer risk level | 9 |
| Walleye | High Intake Fish Consumer | RME $10^{-5}$ cancer risk level | 14 |
| Carp | Carnivorous bird | NOAEC | 14 |
| Carp | Piscivorous mammal | NOAEC | 29 |

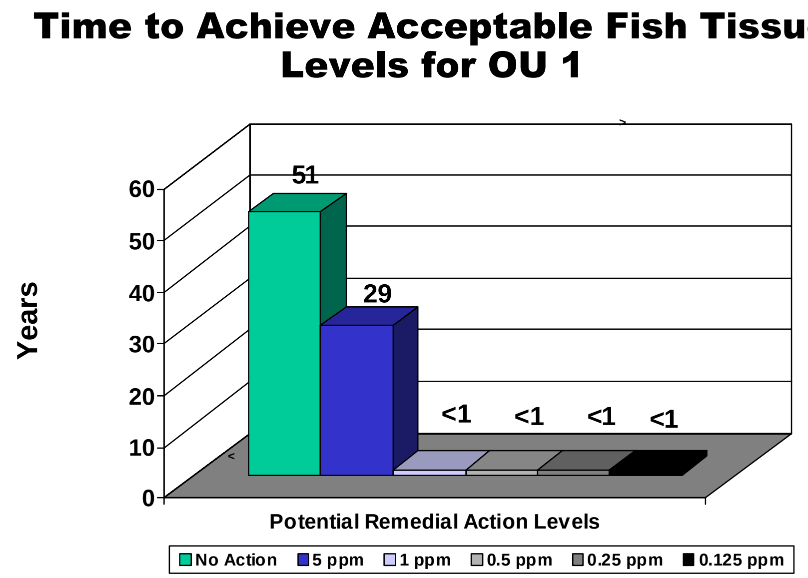
A 1 ppm RAL shows the greatest decrease in projected surface water concentrations. Figure 6 shows model estimates for PCB surface water concentration 30 years after remediation are 2.99 ng/L for No Action, 1.67 ng/L for 5 ppm, and 0.18 ng/L for 1 ppm, which is the largest relative drop. Additional declines for projected surface water concentrations for RAL less than 1 ppm are relatively minimal: 0.13 ng/L, 0.05 ng/L and 0.04 ng/L, respectively for 0.5 ppm, 0.25 ppm and 0.125 ppm RALs. In other words, selection of an RAL less than 1 ppm would only marginally reduce the SWAC and would only marginally reduce surface water concentrations. Thus, a comparison of various RALs shows the 1 ppm RAL has the greatest relative post-remediation decrease in surface water concentrations.

**Figure 6** **Estimates of Surface Water PCB Concentrations for the Evaluated RALs 30 Years After Completion of Remedial Activities for OU 1**



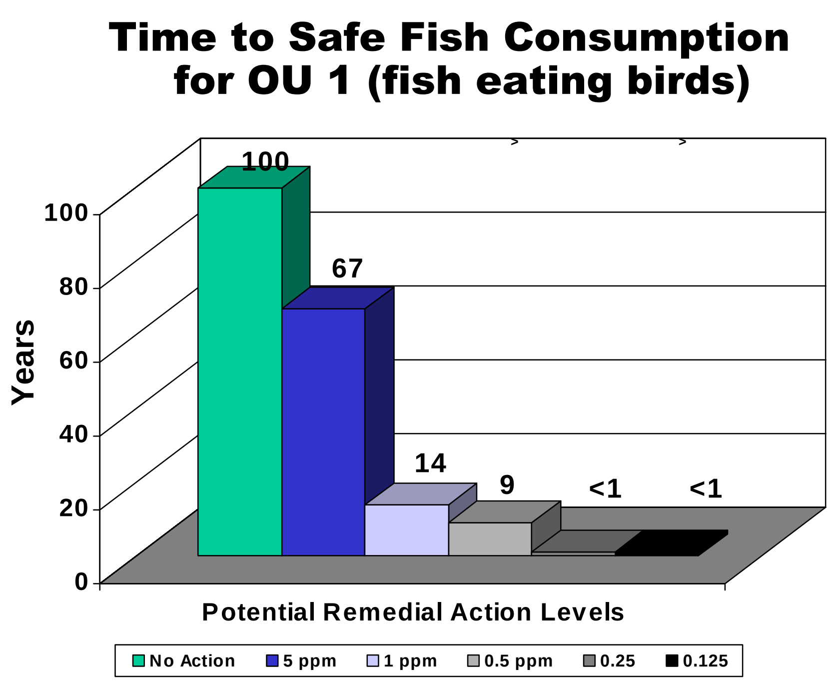

As shown in Figure 7, a 1 ppm RAL shows similar relative decreases in relation to acceptable fish tissue concentrations for walleye. Figure 7 shows that for RAL concentrations greater than 1 ppm, significantly more years will elapse before the risk of fish consumption declines to acceptable levels. The time that it would take to acceptable fish tissue concentrations are 51 years for No Action, 29 years at a RAL of 5 ppm and less than 1 year for a RAL of 1 ppm. The time needed to reach acceptable fish tissue concentrations for RALs less than 1 ppm (0.5 ppm, 0.25 and 0.125 ppm) are almost indistinguishable from the 1 ppm level. Other species of fish show similar reductions and are discussed in detail in the Feasibility Study Chapter 8. Figure 7 clearly shows that there is limited risk reduction achieved by selecting an RAL of less than 1 ppm.

**Figure 7 Time to Achieve Acceptable Fish Tissue Concentrations for OU 1**




Safe fish consumption by birds showed similar relative reductions for 1 ppm versus other potential cleanup levels (Figure 8). For fish eating birds, the time needed to reach safe fish consumption is 100 years for No Action, 67 years for a 5 ppm RAL, 14 years for a 1 ppm RAL (the greatest relative reduction in time), and 9 years for 0.5 ppm RAL. Thus, similar to the earlier figures, the 1 ppm RAL provides the greatest relative reduction of time to ecosystem recovery.

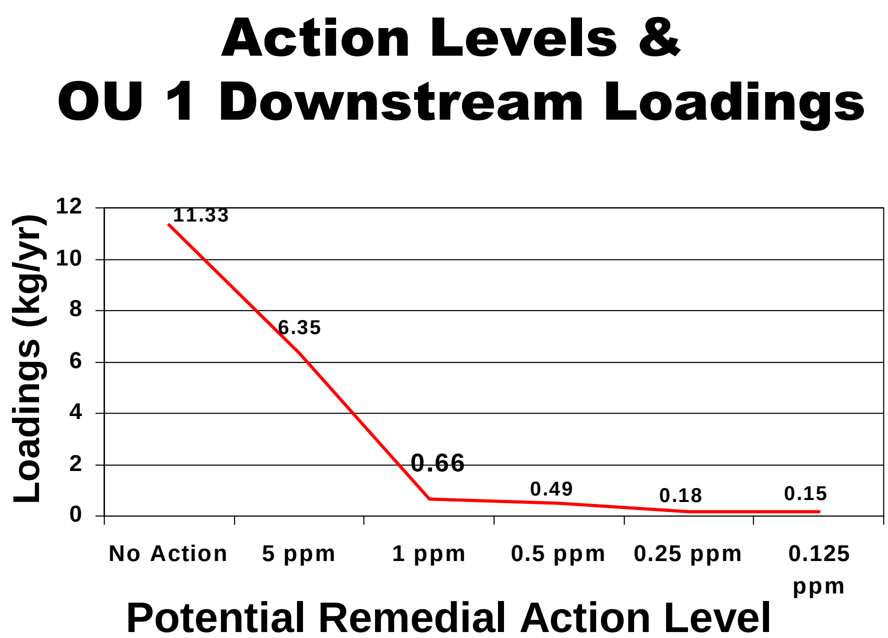
**Figure 8 Time to Safe Fish Consumption by Birds in OU 1**




A 1 ppm RAL is also the most protective based on estimates of downstream loadings (i.e., movement and migration of PCBs into other areas of the River and eventually Green Bay). Downstream loadings of PCBs from OU 1 relative to remedial activities, are as follows: No

Action - 11.33 kg/year, 5 ppm - 6.35 kg/year, 1 ppm – 0.66 kg/year, 0.5 ppm – 0.49 kg/year, 0.25 ppm – 0.18 kg/year, 0.125 ppm – 0.15 kg/year (Figure 9). The RAL of 1 ppm provides the greatest decrease in downstream loadings relative to the other RALs. Like earlier Figures, Figure 9 shows clearly that, with respect to downstream loadings, the 1 ppm RALs level achieves the most reduction.

**Figure 9 RALs and Downstream Loadings in OU 1**




In summary, the 1 ppm RAL shows the greatest relative improvement for all the pertinent RAOs resulting in a protective and cost effective cleanup level for OU 1.

Justification for Monitored Natural Recovery for OU 2

WDNR and EPA have determined that Monitored Natural Recovery (MNR) for OU 2 is sufficiently protective of human health and the environment. However, because of Deposit DD proximately to OU 3, the decision on whether to remediate this deposit will be deferred until the ROD for OU 3 is prepared.

The mass of PCBs and volume of contaminated sediments in OU 2 is approximately 109 kg and 339,200 cubic yards, respectively, for all deposit and interdeposit sediments. This is a small portion (2.4 percent) of the PCB mass and sediment volume in the entire 39 miles of the Lower Fox River, which includes 29,855 kg (66,050 pounds) and 14,061,100 cy, respectively. The 20-miles River reach of OU 2 is a relatively long stretch of the River and includes 22 deposits with relatively small sediment volume and PCB mass. Within OU 2, the deposits with the two largest masses are Deposit N (30 kg [65 pounds]) and Deposit DD (34 kg [74 pounds]). These two deposits account for 58 percent of the total PCB mass in this reach; a majority of the PCB mass at Deposit N was removed during the pilot project at that location, and the agencies will evaluate the feasibility of remediating Deposit DD as part of the OU 3 ROD. Because the removal of all the material from Deposit N is not reflected in the volume estimates in the RI/FS, risk for this reach may be overestimated. An evaluation of sediment volumes within individual deposits in OU 2 shows there are no deposits with a sediment volume greater than 10,000 cy having a PCB concentration above the 1.0 ppm action level. This demonstrates that the areas within this Operable Unit needing remediation are relatively few and that the risk of exposure from one of these areas with higher concentration is low. In addition, the SWAC for OU 2, with no active remediation, is 0.61 ppm. This existing SWAC is close to the 0.25 ppm SWAC goal of OU 1.

In addition to the small physical size and the small quantity of PCB mass within the deposits in this reach, there are numerous impediments, such as the presence of several dams, the physical characteristics of the River in this reach, and the lack of good staging areas, that would cause difficulties in implementation and in mobilizing and operating dredging equipment. These same features also limit the ability to effectively cap the areas within this reach. These impediments would necessitate multiple staging areas. The cost estimate for dredging within this reach at the 1.0 ppm action level is $20.2 million to remove 46,200 cy of contaminated sediment. The cost to remediate this river sediment would be almost $440 /cy.

In addition to the above practical considerations, achieving of contaminant concentration (i.e., risk) reductions would be more difficult for dredging areas where bedrock immediately underlies contaminated sediment. Results on projects such as Deposit N or projects with similar conditions (e.g., Manistique River/Harbor) support the idea that achieving reductions in contaminant concentrations would be difficult. Thus, a dredging remedy for a large portion of this reach would be expected to be less effective and could be more costly for likely only modest risk reduction.

## 13.4 Contingent Remedy - In Situ Capping (i.e., "Partial Capping" or "Supplemental Capping")

WDNR and EPA have selected alternative C as identified in the proposed plan and the RIFS as the *selected* alternative. However, during the RIFS public comment period, the Agencies received numerous comments relating to the viability of capping as a possible remedy. Based on these public comments, WDNR and EPA have developed this contingent remedy that may supplement the selected remedy in certain circumstances. This contingent remedy may only be implemented if it meets the following requirements:

1. The contingent remedy, consisting of a combination of dredging and capping, shall provide the same level of protection to human health and the environment as the selected remedy,
2. This contingent remedy must be less costly than the selected remedy to be implemented,
3. This contingent remedy shall not take more time to implement than the selected remedy,
4. This contingent remedy shall comply with all necessary regulatory, administrative and technical requirements discussed below, and
5. The capping contemplated in this contingent remedy will not be permitted in certain areas of OU 1:
    - No capping in areas of navigation channels (with an appropriate buffer zone).
    - No capping in areas of infrastructure such as pipelines, utility easements, bridge piers, etc (with appropriate buffer zone).
    - No capping in areas with PCB concentrations exceeding TSCA levels.
    - No capping in shallow water areas (bottom elevations which would result in a cap surface at elevation greater than –3 ft chart datum for OU 1 without prior dredging to allow for cap placement.

## 13.5 Basis for Implementing the Contingent Remedy (OU 1)

Use of this contingent remedy may be employed in OU 1 to supplement the selected dredging remedy if one or both of the following criteria are demonstrated. The decision as to whether one or both of the criteria below have been met will be determined solely by the EPA and WDNR.

1) Based on sampling results taken after a sufficient amount of OU 1 dredging of contaminated sediment deposits (e.g., dredging of deposits A/B, C, and POG), it can be predicted with a high degree of certainty that a PCB SWAC of 0.25 ppm would not be achieved for OU 1 by dredging alone, or

2) Capping would be less costly than dredging in accordance with the protectiveness provisions and the nine criteria in the National Contingency Plan (40 CFR 300.430).

In addition to capping areas of OU 1 the selected dredging remedy would still be completed in areas not capped. Based on estimates in the Feasibility Study, and due to limitations on where capping could be done, capping would be limited to less than 25 percent of the total volume of contaminated sediments in OU 1. Selection and implementation of this contingency would be documented in an Explanation of Significant Differences (ESD).

It should be noted that if dredging alone achieves cleanup standards, and the contingent remedy is not shown to be more cost-effective than dredging alone, then capping would not be implemented.

## 13.6 Description of Contingent Remedy

The Contingent Remedy which may supplement the selected remedy, consists of the following components:

- **Cap Design.** Cap construction specifications would be determined during design. Although the Feasibility Study envisioned a cap composed of 20 inches of sand overlain with 12 inches of large cobble “armor” to provide erosion protection, the final cap design would be based on predicted performance. The final cap design must have sufficient thickness to ensure containment of contaminants, resistance to burrowing organisms, and “armoring” to provide sufficient permanence and resistance to erosion and scour.
- **Demobilization and Site Restoration.** Demobilization and Site restoration would require removing all capping-related equipment, fencing, facilities, etc., from staging and work areas.
- **Monitoring.** Operation and maintenance monitoring would be required to ensure proper placement, maintenance of cap integrity, and isolation and containment of contaminants. For this type of capping, monitoring would be performed to ensure that the cap is placed as intended, necessary capping thickness is maintained, and contaminants are contained and do not become bioavailable. In addition to other dredging-related monitoring, cap monitoring would include bathymetric or side-scan sonar profiling, sediment and cap sampling, and capture and analysis of pore water that may migrate through the cap, as well as diver inspections to ensure that the cap is intact and containing contaminants.
- **Institutional Controls.** Institutional controls may include deed restrictions, Site access and anchoring limitations, and continuation of fish and waterfowl consumption advisories as appropriate. Access restrictions could include limitation on the use or development of capped areas, possibly requiring local or State legislative action. These controls and limitations are intended to ensure the permanence of the cap and to minimize re-exposure and/or migration of contaminants.

## 13.7 Estimated Costs of the Contingent Remedy

Costs would be determined prior to implementation of capping. Estimates of capping costs would be documented in an Explanation of Significant Difference (ESD).

# 14. STATUTORY DETERMINATIONS

Under CERCLA Section 121 and the NCP, the remedies that are selected for Superfund sites must be protective of human health and the environment, comply with applicable or relevant and appropriate requirements (unless a statutory waiver is justified), be cost effective, and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity or mobility of hazardous wastes as a principal element and a bias against off-site disposal of untreated wastes. The following sections discuss how the selected remedy meets these statutory requirements.

## 14.1 Protection of Human Health and the Environment

Implementation of the selected remedy will adequately protect human health and the environment through the removal and off-site disposal of PCB-contaminated sediment and the monitoring of the natural recovery of PCB contaminated sediment that is left in place. The selected remedy will target a sediment clean up level of 1.0 ppm in OU 1. This residual risk posed by this action level in OU 1 in years to reach human health and ecological thresholds are presented in Table 30 above. This table indicates that for the selected Action Level of 1.0 ppm, fish advisories for acceptable fish tissue concentrations in walleye would be achieved in 1 to 14 years.

The SWAC value in OU 2 will be 0.61 ppm. Implementation of the selected alternative in OU 1 and OU 2 will result in PCB concentrations within acceptable risk ranges over time. The selected remedy does not pose unacceptable short-term risk.

## 14.2 Compliance with ARARs

Section 121(d) of CERCLA requires that Superfund remedial actions meet ARARs. The selected remedy will comply with the ARARs listed in Table 31.

### 14.2.1 Potential Chemical-Specific ARARs

<u>Toxic Substances Control Act (TSCA)</u>
TSCA establishes requirements for the handling, storage, and disposal of PCB-containing materials equal to or greater than 50 ppm. TSCA is an ARAR at the Site with respect to any PCB-containing materials with PCB concentrations equal to or greater than 50 ppm that are removed from the Site.

<u>Clean Water Act</u>
Federal surface water quality standards are adopted under Section 304 of the Clean Water Act where a state has not adopted standards. These federal standards, if any, are ARARs for point discharges to the River. Related to these standards are the federal ambient water quality criteria. These criteria are non-enforceable guidelines that identify chemical levels for surface

waters and generally may be related to a variety of assumptions such as use of a surface water body as a water supply. These criteria may be TBCs for this Site.

<u>Ground-water Quality Standards</u>
State ground-water quality standards for various substances are set forth in chapter NR 140, Wisconsin Administrative Code (WAC). In general, sections NR 140.24 and NR 140.26 require preventive action limits (PALs) to be achieved to the extent it is technically and economically feasible to do so. In the remediation context, the NR 140 groundwater quality standards are to be achieved within a reasonable timeframe. Natural attenuation is allowed as a remedial method where source control activities have been undertaken and where groundwater quality standards will be achieved within a reasonable period of time. The ground-water quality standards constitute an ARAR.

<u>Soil Cleanup Standards</u>
The State of Wisconsin has adopted generic, site-specific, and performance-based soil cleanup standards. These regulations allow the party conducting the remedial action to select which approach to apply. The generic soil standards are divided into those necessary to protect the ground-water quality and those necessary to prevent unacceptable, direct contact exposure. Generic soil standards, based on conservative default values and assumptions, have been adopted only for a few substances, none of which are relevant to the Site. Site-specific soil standards depend upon a variety of factors, including local soil conditions, depth to groundwater, type of chemical, access restrictions, and current and future use of the property. These site-specific soils standards also may be adjusted based on an assessment of the site-specific risk presented by the chemical constituents of concern. With respect to the Site, the soil standards constitute an ARAR.

<u>Surface Water Quality Standards</u>
The State of Wisconsin has promulgated water quality standards that are based on two components: 1) use designation for the water body; and, 2) water quality criteria. These standards, designations, and criteria are set forth in chapters NR 102 to NR 105, WAC. The state also has rules for applying the water quality standards when establishing water-quality-based effluent limits (chapters NR 106 and NR 207, WAC). The state water quality standards are used in making water management decisions and controlling municipal, business, land development, and agricultural activities (section NR 102.04, WAC). In the remediation context, surface water quality standards are applicable to point source discharges that may be part of the remedial action. Further, to the extent that the remedial work is conducted in or near a water body, such work is to be conducted so as to prevent or minimize an exceedance of a water quality criterion (in chapters NR 102 to 105, WAC).

As recognized in the WDNR's sediment guidance (1995), the water quality standards are goals to be used in guiding the development of the sediment remediation work. As a goal, but not a legal requirement, the water quality standards as applied to the remediation of sediment contamination constitute a TBC.

In addition, the NCP states that, in establishing Remedial Action Objectives (RAOs), water quality criteria established under the Clean Water Act (WQSs in Wisconsin), shall be attained where "relevant and appropriate under the circumstances of the release." 40 CFR 300.430(e)(2)(I)(E).

WDNR and EPA have determined that WQSs, while relevant to sediment clean up RAOs, are not appropriate for direct application at this time. Calculating a site-specific sediment quality standard from a WQS using current scientific methods such as equilibrium partitioning is very uncertain. Moreover, the EPA 's 1996 Superfund PCB clean up guidance directly addresses sediment clean up targets using water quality criteria. The guidance suggests using equilibrium partitioning to develop a sediment criteria and then compare it to risk based clean up numbers for establishing an RAO. If the guidance considered a derived sediment quality number to be an ARAR, it would be directly applied to each alternative as a threshold criteria. Therefore, WQSs are not ARARs and are not a threshold criteria for selecting an alternative for the Site.

### 14.2.2 Potential Action- and Location-Specific ARARs

Wisconsin Statutes Chapter 30

Chapter 30 of the Wisconsin Statutes requires permits for work performed in navigable waterways, or on or near the bank of such a waterway. For remediation that is conducted under CERCLA, only the substantive provisions set forth in Chapter 30 (but not the procedural requirements for obtaining a permit) must be satisfied. In general, the substantive provisions address minimizing any adverse effects on the waterway that may result from the work. This includes chapter NR 116, Wisconsin's Floodplain Management Program. The substantive provisions are action-specific ARARs.

Section 10 - Rivers and Harbors Act; Section 404

**Clean Water Act.** Section 404 of the Clean Water Act requires approval from the USACE for discharges of dredged or fill material into waters of the United States, and Section 10 of the Rivers and Harbors Act requires approval from the USACE for dredging and filling work performed in navigable waters of the United States. As the Fox River is a water of the United States, these statutes might implicate action-specific ARARs for dredging/filling work that may be conducted in the River. Under the Fish and Wildlife Coordination Act, the USACE must coordinate with the Fish and Wildlife Service regarding minimization of effects from such work. The work would be subject to the substantive environmental law aspects of permits under these statutes, which would be ARARs. Permits are not required for remediation that is implemented under the authority of CERCLA.

Floodplain and Wetland Regulations and Executive Orders 11988 and 11990

The requirements of 40 CFR § 264.18 (b) and Executive Order 11988, Protection of Flood Plains, are relevant and appropriate to action on the Site. Executive Order 11990 (Protection of Wetlands) is an applicable requirement if there are any wetlands present in the areas to be remediated.

National Historic Preservation Action (NHPA), 16 U.S.C. 470 et seq

The National Historic Preservation Act (NHPA) provides protections for historic properties (cultural resources) on or eligible for inclusion on the National Historic Register of Historic Places (see 36 CFR Part 800). In selecting a remedial alternative, adverse effects to such properties are to be avoided. If any portion of the Site is on or eligible for the National Historical Register, the NHPA requirements would be ARARs.

Endangered Species

Both State and Federal law have statutory provisions that are intended to protect threatened or endangered species [i.e., Endangered Species Act (Federal) and Fish and Game (State)]. In general, these laws require a determination as to whether any such species (and its related habitat) reside within the area where an activity under review by governmental authority may take place. If the species is present and may be adversely affected by the selected activity, where the adverse effect cannot be prevented, the selected action may proceed. If threatened or endangered species exist in certain areas of the Fox River, these laws may constitute an action-specific ARAR. At the Site, the queen snake as well as several plant species were noted by WDNR to be endangered/rare resources occurring within or near the Site.

Management of PCBs and Products Containing PCBs
Wisconsin regulations (i.e., Chapter NR 157, WAC, "Management of PCBs and Products Containing PCBs" that was adopted pursuant to section 299.45. Wisconsin Statutes) which establish procedures for the storage, collection, transport, and disposal of PCB-containing materials also apply to remedial actions taken at the Site.

Solid Waste Management Statutes and Rules (Chapter 289, Wisconsin Statutes and chapters NR 500-520 & NR 600-685, WAC) establish standards that apply to the collection, transportation, storage and disposal of solid and hazardous waste.

It is not expected that federal Resource Conservation and Recover Act (RCRA) or state regulations governing hazardous waste management will be applicable at this Site.

TSCA – Disposal Approval
TSCA regulations for the disposal of PCB remediation waste (40 CFR 761.61) are applicable to the selection of the clean up alternative for remediation of PCBs in sediments at the Lower Fox River Site, and to the disposal of removed sediments at a State licensed landfill. These regulations provide cleanup and disposal options for PCB remediation waste. The three options include self-implementing, performance-based and risk-based disposal approvals. The risk-based disposal approval option is allowed if it will not pose an unreasonable risk of injury to health and the environment.

The current situation in the Lower Fox River, as identified in RA conducted as part of the RI/FS, is that PCB contaminated sediment pose an unacceptable level of risk in the River at this time. Remediation of PCB contaminated sediment via the selected remedy will reduce risks to human health and the environment.

Sediments removed from the Fox River may contain PCBs equal to or greater than 50 ppm. PCB sediment with concentrations less than 50 ppm will be managed as a solid waste in accordance with statutes and rules governing the disposal of solid waste in Wisconsin. PCB sediment with concentrations equal to or greater than 50 ppm will be managed in accordance with the Toxic Substances Control Act of 1976 (Appendix E of the Feasibility Study). Presently TSCA compliance would be achieved through the extension of the January 24, 1995 approval issued by EPA to WDNR pursuant 40 CFR 761.60(a)(5) under the authority of TSCA. This TSCA approval, granted by EPA Region 5, states that the disposal of PCB-contaminated sediment with concentrations equal to or greater than 50 ppm into an NR 500, WAC landfill that is also in compliance with the conditions of the TSCA approval, provides adequate protection to human health and the environment as required by 40 CFR 761.60(a)(5); and, will provide the same level of protection required by EPA, Region 5 and therefore is no less restrictive than TSCA. However, should other administrative rules pertaining to disposal under TSCA in effect at the time that TSCA compliance decisions are made for the Fox River sediment, then compliance with those rules will be achieved.

### 14.2.3 Additional To Be Considered Information

Section 303(d), Clean Water Act
Under Section 303(d) of the Federal Clean Water Act, states are required, on a periodic basis, to submit lists of "impaired waterways" to EPA. In December 1996, WDNR submitted its first list of impaired waters under Section 303(d). The Fox River was included on the initial list. WDNR has taken no further action with respect to the listing, nor has it developed a total maximum daily load (TMDL) for the River. Currently, a State-wide watershed committee is advising WDNR on the steps to be taken in this process, and the listing process is being reviewed by the

Wisconsin Natural Resources Board. The listing of the Fox River under Section 303(d) is a TBC.

Great Lakes Water Quality Initiative, Part 132, Appendix E

The Great Lakes Water Quality Initiative set forth guidance to the states bordering the Great Lakes regarding their wastewater discharge programs. For remedial actions, the guidance states that any remedial action involving discharges should, in general, minimize any lowering of water quality to the extent practicable. The concepts of the guidance have been incorporated into chapters NR102 to NR 106, WAC. The Great Lakes Water Quality Initiative constitutes a TBC.

Sediment Remediation Implementation Guidance

Part of the Strategic Directions Report of WDNR approved by Secretary Meyer in 1995 addressed the sediment remediation approach to be followed by WDNR. This approach includes meeting water quality standards as a goal of sediment remediation projects. In developing a remedial approach, the guidance calls for use of a complete risk management process in consideration of on-site and off-site environmental effects, technological feasibility, and costs. The guidance constitutes a TBC.

Great Lakes Water Quality Agreement

The Great Lakes Water Quality Agreement calls for the identification of “Areas of Concern” in ports, harbors, and River mouths around the Great Lakes. Remedial goals to improve water quality are to be established in conjunction with the local community. In the case of the Fox River, a Remedial Action Plan (RAP) has been prepared and finalized. The RAP lists a series of recommendations ranging from addressing contaminated sediments to controlling non-point source runoff. This RAP is a TBC.

Fox River Basin Water Quality Management Plan

This plan was developed by WDNR and lists management objectives for improving water quality in the Fox River Basin. The Fox River Basin Water Quality Management Plan is a TBC.

**Table 31 Fox River ARARs**

| Act / Regulation | Citation |
|---|---|
| **Federal Chemical-Specific ARARs** | |
| TSCA | 40 CFR 761.60(a)(5)-761.79 and U.S. EPA Disposal Approval |
| Clean Water Act – Federal Water Quality Standards | 40 CFR 131 (if no Wisconsin regulation) and 33 CFR 323 |
| **Federal Action-/Location - Specific ARARs** | |
| Fish and Wildlife Coordination Act | 16 USC 661 *et seq.*<br>33 CFR 320-330-Rivers and Harbors Act<br>40 CFR 6.304 |
| Endangered Species Act | 16 USC 1531 *et seq.*<br>50 CFR 200<br>50 CFR 402 |
| Rivers and Harbor Act | 33 USC 403; 33 CFR 322, 323 |
| National Historic Preservation Act | 15 USC 470; *et seq.* 36 CFR Part 800 |
| Floodplain and Wetlands Regs & Executive Orders | 40 CFR 264.18 (b) and Executive Order 11988 |

| Act / Regulation | Citation |
|---|---|
| **State Chemical-Specific ARARs** | |
| TSCA-Disposal Approval | U.S. EPA Approval |
| Surface Water Quality Standards | NR 102, 105 and 207<br>NR 722.09 1-2 |
| Ground-Water Quality Standards | NR 140 |
| Soil Cleanup Standards | NR 720 and 722 |
| Hazardous Waste Statutes and Rules | NR 600 - 685 |
| **State Action- / Location-Specific ARARs** | |
| Management of PCBs and Products Containing PCBs | NR 157 |
| Wisconsin's Floodplain Management Program | NR 116 |
| Solid Waste Management | NR 500-520 |
| Navigable Waters, Harbors, and Navigation | Chapter 30 - Wisconsin Statutes |
| Fish and Game | Chapter 29.415 - Wisconsin Statutes |

## 14.3 Cost-Effectiveness

WDNR and EPA have determined that the selected remedy is cost effective. Section 300.430 (f)(1)(ii)(D) of the NCP requires that all the alternatives that meet the threshold criteria (protection of human health and the environment and compliance with ARARs) must be evaluated by comparing their effectiveness to the three balancing criteria (long-term effectiveness and permanence, reduction of toxicity, mobility or volume through treatment, and short-term effectiveness). The selected remedies meet these criteria by achieving a permanent protection of human health and the environment at low risk to the public, and provide for overall effectiveness in proportion to their cost.

The Superfund program does not mandate the selection of the least costly cleanup alternative. The least costly effective remedy is not necessarily the remedy that provides the best balance of tradeoffs with respect to the remedy selection criteria nor is it necessarily the least-costly alternative that is both protective of human health and the environment and ARAR-compliant. Cost effectiveness is concerned with the reasonableness of the relationship between the effectiveness afforded by each alternative and its costs compared to other available options.

The total net present worth of the selected remedy for OU 1 and OU 2 is $76.5 million.

## 14.4 Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable

WDNR and EPA believe that the selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a cost-effective manner for the Fox River Site. The selected remedy does not pose excessive short-term risks. There are no special implementability issues that set the selected remedy apart from the other alternatives evaluated.

## 14.5 Preference for Treatment as a Principal Element

Based on current information, WDNR and EPA believe that the selected remedy is protective of human health and the environment and utilizes permanent solutions to the maximum extent possible. The remedy, however, does not satisfy the statutory preference for treatment of the hazardous substances present at the Site as a principal element because such treatment was not found to be practical or cost effective.

### 14.6 Five-Year Review Requirements

The NCP, at 40 CFR § 300.430(f)(4)(ii), requires a five-year review if the remedial action results in hazardous substances, pollutants, or contaminants remaining on site above levels that allow for unlimited use and unrestricted exposure. Because this remedy will result in hazardous contaminants remaining on site above levels that allow for unlimited exposure, a statutory review will be conducted within five years after initiation of the remedial action to ensure that the remedy is, or will be, protective of human health and the environment.

## 15. DOCUMENTATION OF SIGNIFICANT CHANGES FROM PREFERRED ALTERNATIVE OF PROPOSED PLAN

To fulfill the requirements of CERCLA 117(b) and NCP [40 CFR § 300.430(f)(5)(iii)(B) and 300.430(f)(3)(ii)(A)], a ROD must document and discuss the reasons for any significant changes made to the Proposed Plan.

The Proposed Plan was released for public comment in October 2001. It identified a PCB sediment clean up target of 1.0 ppm in OU 1 with monitored natural recovery in OU 2.

In the selection of the remedy for OU 1 and OU 2, the WDNR and EPA considered information submitted during the public comment period re-evaluated portions of the proposed alternative.

<u>New Information obtained during the Public Comment Period</u>
WDNR and EPA considered alternative proposals for OU 1 submitted as comments. As a result of consideration of these comments, the following were incorporated into this Record of Decision: 1) If dredging is unable to reduce exposed contaminants PCB concentrations, a sand cover will be employed to further reduce risks, rather than continue with dredging removal operations (Section 13.3); and 2) if it is predicted, based on results from partial completion of dredging OU 1, that concentrations may not sufficiently reduce risks, or if capping is shown to be less costly than complete dredging, then capping may be employed for some areas not yet dredged (Section 13.4).

These proposals may be given further consideration prior to implementation of remedial actions. However if these proposals cause a fundamental change to the alternatives described in this decision (e.g., changing the remedy from removal to containment), then WDNR and EPA would issue a new, revised Proposed Plan and would have a public comment period after which a ROD Amendment would be finalized. If the change is not “fundamental,” but “significant” (e.g., modification of volumes to be removed), then an Explanation of Significant Difference would be issued, and there would be limited public comment.

# Responsiveness Summary

## Lower Fox River and Green Bay, Wisconsin Site

## Record of Decision, Operable Units 1 and 2

**Wisconsin Department of Natural Resources**
**101 S. Webster Street**
**Madison, Wisconsin 55703**

**Wisconsin Department of Natural Resources**
**Northeast Region**
**1125 N. Military Avenue**
**Green Bay, Wisconsin 54307**

**U.S. Environmental Protection Agency**
**Region 5 Superfund**
**77 W. Jackson Boulevard**
**Chicago, Illinois 60604**

**December 2002**

# Responsiveness Summary

## Lower Fox River and Green Bay, Wisconsin Site

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## December 2002

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# List of White Papers

# List of Acronyms

| | |
|---|---|
| AEHS | Association for Environmental Health and Sciences |
| Agencies | United States Environmental Protection Agency and Wisconsin Department of Natural Resources |
| AGI | American Geological Institute |
| API | Appleton Papers, Inc. |
| API Panel | Appleton Paper, Inc. Panel |
| ARAR | applicable or relevant and appropriate requirement |
| ARCS | Assessment and Remediation of Contaminated Sediments |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BBL | Blasland, Bouck & Lee |
| BCC | Bioaccumulative Chemical of Concern |
| BDAT | Best Demonstrated Available Technology |
| Be-7 | beryllium-7 |
| BLRA | Baseline Human Health and Ecological Risk Assessment |
| BOD | biochemical oxygen demand |
| BTAG | Biological Technical Assistance Group |
| CDF | confined disposal facility |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| cm | centimeter |
| COC | chemical of concern |
| COPC | chemical of potential concern |
| Cs-137 | cesium-137 |
| CSF | cancer slope factor |
| CTE | central tendency exposure |
| CWA | Clean Water Act |
| CWAC | Clean Water Action Council |
| cy | cubic yard |
| DDE | 4,4'-dichlorodiphenyl dichloroethylene |
| DDT | 4,4'-dichlorodiphenyl trichloroethylene |
| DO | dissolved oxygen |
| ED | exposure duration |
| EIS | Environmental Impact Statement |
| EPA | United States Environmental Protection Agency |
| ESA | Endangered Species Act |
| FERC | Federal Energy Regulatory Commission |
| FHTB | Fort Howard Turning Basin |
| FRDB | Fox River Database |
| FRFood | Fox River Food Chain Model |
| FRG | Fox River Group |
| FRRAT | Fox River Remediation Advisory Team |
| FS | Feasibility Study |
| ft/s | feet per second |
| GBFood | Green Bay Food Chain Model |

# List of Acronyms

| | |
|---|---|
| GBMBS | Green Bay Mass Balance Study |
| GBTOXe | Enhanced Green Bay PCB Transport Model |
| g/cy | grams per cubic yard |
| GFT | glass furnace technology |
| GLNPO | Great Lakes National Program Office |
| GLWQI | Great Lakes Water Quality Initiative |
| $g/m^2$ | grams per square meter |
| GRA&I | Government Report Announcements and Index |
| HIS | Habitat Suitability Index |
| HHRA | Human Health Risk Assessment |
| HTTD | high-temperature thermal desorption |
| IDW | inverse-distance-weighing |
| IFIM | In-Stream Flow Incremental Methodology |
| IGP | Intergovernmental Partnership |
| ISC | *in-situ* capping |
| kg | kilogram |
| LaMP | Lake-wide Management Plan |
| LOAEL | lowest observed adverse effects level |
| LOD | limit of detection |
| LTI | Limno-Tech, Inc. |
| LTMP | Long-term Monitoring Plan |
| MDR | Model Documentation Report |
| MEP | model evaluation process |
| mgd | million gallons per day |
| mg/kg | milligrams per kilogram |
| MNR | Monitored Natural Recovery |
| MOA | Memorandum of Agreement |
| MOU | Memorandum of Understanding |
| NAS | National Academies of Science |
| NCP | National Contingency Plan |
| NEPA | National Environmental Policy Act |
| ng/L | nanograms per liter |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAEL | no observed adverse effects level |
| NPL | National Priorities List |
| NRC | National Research Council |
| NRDA | Natural Resources Damage Assessment |
| OSWER | Office of Solid Waste and Emergency Response |
| OU | Operable Unit |
| Panel Report | Ecosystem-Based Rehabilitation Plan |
| PCB | polychlorinated biphenyl |
| PKC | Protein Kinase C |
| POTW | publicly-owned treatment works |
| ppm | parts per million |
| Proposed Plan | Proposed Remedial Action Plan |

# List of Acronyms

| | |
|---|---|
| PRP | Potentially Responsible Party |
| QA/QC | quality assurance/quality control |
| RAGS | Risk Assessment Guidance for Superfund |
| RAL | Remedial Action Level |
| RAO | Remedial Action Objective |
| RAP | Remedial Action Plan |
| RD/RA | remedy design and remedial action |
| RfD | reference dose |
| RI | Remedial Investigation |
| RI/FS | Remedial Investigation and Feasibility Study |
| RME | reasonable maximum exposure |
| ROD | Record of Decision |
| RS | Responsiveness Summary |
| RSS | Root-Sum-of-Squares |
| SAV | submerged aquatic vegetation |
| Site | Lower Fox River and Green Bay Site |
| SITE | Superfund Innovative Technology Evaluation |
| SMU | Sediment Management Unit |
| SQT | Sediment Quality Threshold |
| STAC | Science and Technical Advisory Committee |
| SWAC | Surface-Weighted Average Concentration |
| T&E | threatened and endangered |
| TAG | Technical Assistance Grant |
| TBC | To be Considered |
| TEF | toxic equivalency factor |
| TEQ | toxic equivalency |
| TM | Technical Memorandum |
| TM2g | Technical Memorandum 2g |
| TM5c | Technical Memorandum 5c |
| TM7c | Technical Memorandum 7c |
| TMDL | total maximum daily load |
| TMWL | The Mountain-Whisper-Light Statistical Consulting |
| TOC | total organic carbon |
| TRV | toxicity reference value |
| TSCA | Toxic Substances Control Act |
| TTA | Time Trends Analysis |
| UCL | upper confidence limit |
| USACE | United States Army Corps of Engineers |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| WAC | Wisconsin Administrative Code |
| WDNR | Wisconsin Department of Natural Resources |
| WHO | World Health Organization |
| WLA | waste load allocation |
| wLFRM | Whole Lower Fox River Model |

# List of Acronyms

| | |
|---|---|
| Work Plan | Work Plan to Evaluate the Fate and Transport Models for the Fox River and Green Bay |
| WPDES | Wisconsin Pollutant Discharge Elimination System |
| WQBEL | Water Quality Based Effluent Limits |
| WQS | Water Quality Standards |
| WTMI | formerly Wisconsin Tissue |
| WUATM | Wisconsin Department of Natural Resource’s Urban Air Toxics Monitoring |
| ww | wet weight |
| WWTF | wastewater treatment facility |

# Executive Summary

This *Responsiveness Summary – Lower Fox River and Green Bay, Wisconsin Site Record of Decision, Operable Units 1 and 2* (RS) is the culmination of the comment process for the Wisconsin Department of Natural Resource's (WDNR's) and the United States Environmental Protection Agency's (EPA's) *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) and the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS). These documents have had the benefit of an extensive public-involvement program. Even before the initiation of the formal public comment period, there had been numerous meetings/forums with the public.

In February 1999, a draft RI/FS was released with a 45-day public comment period, which was extended an additional 60 days. Public meetings and Proposed Plan availability sessions were announced to the public at a press conference on October 5, 2001, and received extensive coverage through television, radio, and newspaper stories. Copies of the various supporting reports and the Proposed Plan were made available to the public during a public comment period that began on October 5, 2001 and concluded on January 22, 2002.

The final RI/FS and Proposed Plan were formally presented at public meetings held on October 29, 2001 in Appleton, Wisconsin and October 30, 2001 in Green Bay, Wisconsin, where oral and written comments were accepted. Additionally, WDNR and EPA mailed meeting reminders and Proposed Plan summaries to the 10,000-name Lower Fox River mailing list recipients. Press releases pertaining to the Proposed Plan, comment period, and public meetings were also sent to newspapers, television and radio stations throughout the Fox River Valley.

Newspaper advertisements were placed in the *Green Bay Press Gazette* and the *Appleton Post Crescent* announcing the availability of the Proposed Plan and its supporting documents, and a brief summary of the Proposed Plan was placed in the information repositories. The Proposed Plan, the RI/FS, and other supporting documents containing information upon which the proposed alternative was based were also made available on the WDNR's website. In response to this public outreach, WDNR and EPA received approximately 4,800 written comments via letter, fax, and e-mail.

It was through this extensive effort that WDNR and EPA-derived the remedial action plan set forth in the Record of Decision (ROD), which is being released at this time and to which this RS is attached.

What follows in this Executive Summary is an abbreviated discussion of some of the comments addressed and responded to in the RS, beginning with the background and description of the Lower Fox River and Green Bay Site and salient elements of the ROD. For each, a more detailed discussion can be found within the main body of this RS.

## Site Description and Background

The Lower Fox River (River) and Green Bay (Bay) Site includes an approximately 39-mile stretch of the Lower Fox River and the Bay to its entry into Lake Michigan (Site). The River portion of the Site extends from the outlet of Lake Winnebago and continues downstream to the River's mouth at Green Bay, Wisconsin. The Bay portion of the Site includes all of Green Bay from the city of Green Bay to the point where Green Bay enters Lake Michigan.

For many years along the River, there have been and continue to be located an intense concentration of paper mills. Some of these mills operated de-inking facilities in connection with the recycling of paper. Others manufactured carbonless copy paper. In both the de-inking operations and the manufacturing of carbonless copy paper, these mills handled polychlorinated biphenyls (PCBs), which were used in the emulsion that coated carbonless copy paper. In the de-inking process and in the manufacturing process, PCBs were released from the mills to the River directly or after passing through local water treatment works. PCBs have a tendency to adhere to sediment and, consequently, have contaminated the River sediments. In addition, the PCBs and contaminated sediments were carried downriver and into the Bay.

For ease of management and administration, the Site has been divided into certain discrete areas (Operable Units [OUs]). The River has been divided into OUs 1 through 4 and Green Bay constitutes OU 5. These OUs are as follows:

- OU 1 – Little Lake Butte des Morts
- OU 2 – Appleton to Little Rapids
- OU 3 – Little Rapids to De Pere
- OU 4 – De Pere to Green Bay
- OU 5 – Green Bay

## Record of Decision

This ROD selects a remedial action for OUs 1 and 2. A second ROD, addressing OUs 3 through 5, also will be issued in the future. The estimated cost for the remedial action in OU 1 is $66.2 million and for OU 2 it is $9.9 million.

As with many Superfund sites, the problems presented by the Site are complex. The Proposed Plan, released in October 2001, recommended a cleanup plan for all five OUs at the Site. The RI/FS and the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin Remedial Investigation and Feasibility Study* (BLRA) also cover all five OUs. The reasons for issuing an ROD at this time for only OUs 1 and 2 are as follows:

- OUs 1 and 2 represent a smaller portion of the area within the River where remediation is necessary. These two OUs represent approximately 6.5 percent of the PCB mass and 18 percent of the sediment volume in the River. Consequently, these two OUs represent a project of more manageable size than conducting all of the remediation at one time.

- To provide a phased approach to the remedial work, work on upstream areas can start before the downstream areas, which is consistent with EPA policy.

- Planning for OUs 3, 4, and 5 may benefit from knowledge gained from the remedial activities conducted for the OUs 1 and 2 project.

This ROD addresses human health and ecological risks posed to people and ecological receptors associated with PCBs that have been released to the Site. Presently, these PCBs reside primarily in the sediments in the River and in the Bay, and this ROD outlines a remedial plan to address a certain portion of PCB-contaminated sediments. Removal of PCB-contaminated sediments will result in reduced PCB concentrations in fish tissue, thereby accelerating the reduction in potential future human health and ecological risks. In addition, by addressing upstream contamination first, the downstream transport of PCBs will be dramatically reduced and will not interfere with further remediation efforts downstream.

Presently, it is estimated that OU 1 contains approximately 4,070 pounds (1,850 kilograms [kg]) of PCBs in 2,200,400 cubic yards (cy) of sediment. The ROD provides for the removal by hydraulic dredging of an estimated 784,000 cy of contaminated sediments from OU 1. The dredged material will be mechanically “dewatered” and taken to a landfill for permanent disposal. The ROD establishes an “action level” of 1 part per million (ppm) for this cleanup effort. In other words, any sediment found in OU 1, which has a concentration of PCBs of 1 ppm or greater, will be targeted for removal. The goal of the remedial action in OU 1 is to reach a surface-weighted average concentration (SWAC) of less than 0.25 ppm after dredging is completed. This means that the concentration of PCBs averaged over the entire OU will not exceed 0.25 ppm when the cleanup is complete. By reducing the concentration of PCBs in OU 1 to the SWAC level, or below, will dramatically reduce the human health and ecological risk.

Operable Unit 2, which is about 22 miles in length, contains approximately 240 pounds (109 kg) of PCBs in 339,200 cy of sediment. A significant portion of the PCBs contained in this OU have already been removed during the sediment removal demonstration project at Deposit N. The result is that in OU 2 there remain no significant (i.e., greater than 10,000 cy) contaminated sediment deposits with concentrations of PCBs above the action level. Moreover, it is contemplated that the farthest downstream deposit in OU 2 (Deposit DD) may be remediated in connection with the remedial action to be undertaken in OU 3 at a later time. Even without active remediation, the SWAC for OU 2 is low, approximately 0.61 ppm, which is below the remedial action objective (RAO) of 1 ppm. Therefore for OU 2 the ROD selects a remedy of monitored natural recovery (MNR). This remedy does not involve sediment removal. Rather, it consists of a comprehensive monitoring program designed in part to monitor the levels of PCBs in sediments as the natural recovery processes work. Coupling this MNR with the substantial upstream dredging remedy in OU 1 should result in very minimal human health or ecological risk in OU 2.

## Comments and Responses

### Policy Issues

Many comments were received regarding policy issues and selection of the preferred remedy. In 2001, the National Research Council (NRC) issued findings addressing the complex issues associated with the managing of PCB-contaminated sediment sites. EPA issued guidance in 2002 for managing risks at contaminated sediment sites. The Lower Fox River and Green Bay Site RI/FS and its supporting documents and actions are consistent with the principles defined by the EPA and with the NRC recommendations contained in *A Risk Management Strategy for PCB-contaminated Sediments*. Each of the 11 EPA principles and how they were applied to the Lower Fox River and Green Bay RI/FS are fully set forth in *White Paper No. 10 – Applicability of the NRC Recommendations for PCB-Contaminated Sites and EPA's 11 Management Principles*.

In the review of comments, the WDNR and EPA (Agencies) concluded that there is merit in adopting an adaptive management approach for dealing with the complex remediation of the Lower Fox River and Green Bay. Splitting the overall Site remediation plan into two RODs will allow for a phased approach. Issuing the ROD for OUs 1 and 2 at this time and then issuing an ROD for OUs 3 through 5 at a later date will allow the Agencies to apply any "lessons learned" on OUs 1 and 2 for implementing or modifying remedies for OUs 3 through 5. The Agencies also believe that by including the consideration of a capping alternative, the flexibility of this ROD is enhanced in a manner consistent with an adaptive management approach.

### Time Trends Analysis

Many comments were received regarding the comprehensive time trends analysis (Time Trends Analysis [TTA]) conducted for the RI (Appendix B). Criticisms generally followed those in the analyses presented in two papers submitted in rebuttal to the TTA: *BB&L Report on PCB Trends in Fish from the Lower Fox River* and *Time Trends in PCB Concentrations in Sediment and Fish, Lower Fox River, Wisconsin* by Dr. Paul Switzer.

Issues raised by commenters included the following:

- Declines in PCB concentrations in fish tissue, sediments, and water were not used or improperly applied in the RI/FS and Proposed Plan;
- That there was no basis for the breakpoint established in the TTA, which shows a leveling off of fish tissue concentrations (the "breakpoint analysis");
- Alternatively, commenters contended that PCB concentrations in fish tissue are continuing to show decline within the River; and
- Further, the TTA used an inappropriate statistical model, did not make the best use of the available data, and that a simple mathematical representation of the data shows a long-term, consistent downward trend.

Central to these arguments is that the selection of the remedial activities would be inappropriately based on this analysis in the TTA. WDNR and EPA address these criticisms in both the response to comments and in *White Paper No. 1 – Time Trends Analysis*. As these responses show, the TTA analysis is appropriate, and WDNR and EPA have correctly relied upon it.

## Economic Impacts

Numerous commenters expressed concern about local economic impacts on the Fox River Valley of a large-scale, expensive remedial action in the River. WDNR and EPA share these concerns about the potential impacts that this action, as well as future actions, may have on the Fox River Valley and Green Bay community. Furthermore, WDNR and EPA believe that one of the keys to minimizing remedial costs is to work with the local community and businesses. To begin to address these concerns, the WDNR has supported legislation to indemnify municipal landfills and public-owned treatment works (POTWs) that accept sediment and leachate from sediment remediation projects (S. 292.70 Wisconsin State Statutes). EPA has publicly stated that it may invoke its enforcement discretion to reduce the economic burden on the Fox River Valley municipalities. In addition, EPA has completed an economic assessment of the capability of those entities, identified as potentially responsible parties (PRPs), to fund the work called for in the ROD. EPA's analysis is contained *White Paper No. 17 – Financial Assessment of the Fox River Group*. The major conclusion of that assessment was that those entities can collectively shoulder the costs of this remedy without financial hardship.

## Alternative Remediation Plans

As part of the submittals during the public comments period, WDNR and EPA received an alternative remediation plan from a panel of university professors and scientists, experts hired by Appleton Papers, Incorporated (API) entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (the “Panel Report”). This plan focused on the feasibility of capping major portions of the River in lieu of the remedy contained in the Proposed Plan. The Agencies address this proposal in Section 5.5 of the RS and in several of the white papers (e.g., *White Paper No. 6A – Comments on the API Panel Report*; *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* and *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component of the Lower Fox River*).

This alternative plan generated a number of comments, both in favor and against the Panel Report. In the RS, the Agencies address the comments regarding the Panel Report, but do not address the comments received on this alternative capping plan because that alternative plan was not part of the Agencies’ Proposed Plan, and the Agencies are not the authors of that alternative plan.

## Models

Numerous comments were received that questioned the models used in investigation of and derivation of the remedial alternatives. Commenters from the Fox River Group (FRG) (a coalition of six companies) submitted an alternative computer model known as FoxSim and made various claims based on the forecasts generated by FoxSim. In some cases, comparing those forecasts to the modeling work identified in the *Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin* (MDR). In response to the submittal of the FoxSim model, WDNR’s Water Quality Modeling Section reviewed FoxSim. The primary conclusions of that review was that the FoxSim model contains high uncertainties in its ability to predict PCB fate and transport in the Lower Fox River system, and that the FoxSim model was constructed with a stated bias to “evaluate the on-going and future natural attenuation of the system.” This is accomplished through the model’s prediction of deposition of clean sediments and less scour of contaminated sediments, which leads to a prediction of less availability of PCBs to the water column and transport of PCBs within the River, and from the River to Green Bay. Please see *White Paper No. 15 – FoxSim Model Documentation* for more information.

The Agencies have also reviewed comments made on the current model being used to assist in the assessment and evaluation of impacts of the remedial alternatives, the Whole Lower Fox River Model (wLFRM). The Agencies believe that they have addressed the wLFRM comments and concerns and have confidence in wLFRM model. Section 6 of this RS addresses these comments on the models used in the investigation and selection of the remedial alternatives.

### RALs, SWACs, SQTs, and RAOs

WDNR and EPA selected the 1 ppm action level based on an evaluation of a range of Remedial Action Levels (RALs) with the residual SWAC for OU 1 and the ability of the action level to meet the RAOs. The RALs evaluated included no action, 0.125, 0.25, 0.5, 1, and 5 ppm. The selection of the cleanup level is the outcome of a complete and scientifically based risk evaluation. Before selecting 1 ppm, WDNR and EPA carefully considered the RAOs, model forecasts of the post remediation time required to achieve risk reduction, the post-remediation SWAC, comparison of the residual concentration to Sediment Quality Thresholds (SQTs) for human and ecological receptors, sediment volume and PCB mass to be managed, as well as cost. The 1 ppm action level represented the optimum action level for achieving these goals.

In OU 1, the post-remediation time required to reach the endpoints for risk reduction varies by receptor from less than 1 year to an estimated 29 years. As was pointed out in earlier documents (e.g., the Proposed Plan), the upstream reach achieves risk reduction faster than does the area around the mouth of the River. The SWAC in OU 1 is a measure of the surface (upper 10 centimeters [cm]) concentration and would be 0.19 ppm if all material greater than 1 ppm is removed. The SWAC value provides a number that can be compared to the SQTs developed in the BLRA. SQTs are estimated concentrations that relate risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. A comparison of the SWAC and SQT values shows that there is an overlap of the various SQT values for recreational anglers, high-intake fish consumers, and wildlife, and the SWAC value for OU 1.

WDNR and EPA believe this is also consistent with the 1999 Draft RI/FS. The 1999 Draft RI/FS called for an action level of 0.25 ppm or a 0.25 ppm SWAC. The predicted SWAC value resulting from the 1 ppm action level is approximately 0.19 ppm in OU 1. For further discussion, please review the supporting document that explains the relationship of the action level to the SWAC; *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

## Conclusion

WDNR and EPA, after extensive public involvement and input, have selected a remedy for the Site, which will achieve the RAOs as set forth in the Proposed Plan and attached ROD. The following RS represents the comments and responses from the comment period and were used in selecting the final remedy presented in the ROD.

Complete copies of the Lower Fox River and Green Bay Site ROD and RS for OUs 1 and 2 are available to the public at five public repositories in the Fox River Valley as well as being posted on the WDNR's web page for the Lower Fox River (http://www.dnr.state.wi.us/org/water/wm/lowerfox/index.html). In addition, the Administrative Record for the Site is available at the WDNR's offices in Green Bay and in Madison. Information repositories are located at the Appleton Public Library, Oshkosh Public Library, Brown County Library in Green Bay, Door County Library in Sturgeon Bay, and Oneida Community Library.

# 1 Legal, Policy, and Public Participation Issues

## 1.1 Policy Issues

### Master Comment 1.1

Commenters stated that capping as a remedy for sediments contaminated with polychlorinated biphenyls exceeding the Toxic Substances Control Act (TSCA) level (50 ppm) was not included in the FS. Commenters further stated that the criteria for eliminating capping of TSCA-level sediments based on the EPA disapproval letter has no regulatory basis. The concerns raised were that EPA, in fact, may approve of TSCA capping under the risk-based disposal approval 40 Code of Federal Regulations (CFR) § 761.61((c)) as "PCB remediation waste." Further, commenters stated that TSCA does not exclude capping of any sediment area with PCB concentrations greater than 50 ppm, unless all sediments with concentrations greater than that level are removed through dredging first.

### *Response*

WDNR and EPA agree that TSCA regulations may not prohibit capping at the Lower Fox River Site. TSCA is applicable and would be considered in the remedy selected.

The Agencies do not recommend capping in areas with PCB concentrations exceeding TSCA levels. The presence of PCBs with concentrations exceeding 50 ppm presents some constraints for capping with respect to TSCA. The ability of an *in-situ* cap to meet the requirements of TSCA has not been fully established. TSCA-level sediments are present only in limited areas of OUs 1, 3, and 4. Based on these considerations, no capping of TSCA-level sediments should be considered.

In addition, *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* contains a relevant discussion of this topic.

### Master Comment 1.2

Commenters indicated that WDNR should support and pursue legislative protection for local governments in connection with any remediation alternatives selected for the Lower Fox River.

### *Response*

WDNR has done this in that the Agency supported the passing of legislation to indemnify municipal landfills and POTWs that accept sediment and leachate from sediment remediation projects (S.292.70 Wisconsin State Statutes). Moreover, while a number of municipalities may technically fit within the Superfund Section 107(a) categories of "potentially responsible parties," both WDNR and EPA management have made statements publicly that the State and federal governments are not inclined to seek large dollar-figure reimbursement from those municipalities. Instead, as an exercise of its "enforcement discretion," it is much more likely that the State and federal governments may seek in-kind services and other assistance from those municipalities as a part of any settlement that may be achieved for the Lower Fox River cleanup.

# 1.2 CERCLA Requirements and Issues

## Master Comment 1.3

Some commenters contend that the FS is required to address the potential environmental impacts in a manner that would meet the standards of "functional equivalency" in an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA).

## *Response*

This very issue is dealt with in detail in the Hudson River Responsiveness Summary, Master Comment 475. In that document, EPA noted the following:

> CERCLA requires EPA to comply only with the substantive, and not the procedural, requirements of other environmental laws for CERCLA response actions that are conducted onsite (Section 121(d)(2)(A) of CERCLA, 42 U.S.C. § 9621(d)(2)(A); Section 121(e) of CERCLA, 42 U.S.C. § 9621(e); 40 CFR § 300.5 (definitions of "applicable requirements" and "relevant and appropriate requirements"); and State of Ohio v. U.S. E.P.A., 997 F.2d 1520, 1526 (D.C. Cir. 1993) (ARARs include only substantive, and not procedural, requirements). See also EPA guidance document CERCLA Compliance with Other Laws Manual: Part II, Clean Air Act and Other Environmental Statutes and State Requirements (OSWER Directive 9234.1-02 [August 1989], p. 4-1). NEPA's requirements are procedural, and, therefore, do not apply to on-site CERCLA response actions. Any dredging activity and dewatering/transfer facility for the Hudson [Lower Fox River] PCBs remedy would be considered on-site (40 CFR 300.400(e)(1)): "The term on-site means the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action."
>
> Moreover, EPA stated that it considers the procedures established by the CERCLA for investigation and response at hazardous waste sites, which are further detailed in the NCP, and which were complied with during the Hudson River PCBs Reassessment, to be the functional equivalent of NEPA. This consideration is based on the extensive analysis of alternatives and environmental impacts, and the aggressive community involvement program, established by CERCLA. As a number of courts have held, where the authorizing statute (in this case, CERCLA) already provides for a detailed analysis of environmental impacts, EPA will satisfy necessary environmental review requirements by following CERCLA, and will not have to separately comply with NEPA (e.g., State of Alabama ex rel. Siegelman v. EPA, 911 F.2d 499 [$11^{th}$ Cir. 1990]).

> Functional equivalence does not mean structural or literal equivalence, and does not require EPA to consider every point or issue that would otherwise be addressed in an environmental impact statement (State of Alabama ex rel. Siegelman, 911 F.2d 504-505). CERCLA's substantive and procedural requirements, followed here, nevertheless ensure that EPA considers appropriate environmental issues relating to remedy selection, and allows the public to participate in the remedy selection process.
>
> Some comments argue that CERCLA and the NCP require EPA to provide detailed analyses of potential noise, odor, lighting, transportation, and resuspension impacts of the preferred remedy, and to identify the locations of the proposed dewatering/transfer facility(ies), and that such information should have been included in the FS in order to satisfy the functional equivalence standard. The analysis of potential short-term impacts of the preferred remedy in the FS, however, was performed in accordance with CERCLA and the NCP, and is, therefore, functionally equivalent to a NEPA analysis. EPA's analysis of potential short-term impacts was also consistent with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (OSWER 9355.3-01) (October 1988).

The commenters also go on to assert that there may be adverse impacts associated with dredging, and imply that the following issues should be addressed in the FS:

- **Habitat, Wildlife, and Threatened and Endangered Species:** The Final BLRA and the FS thoroughly document that past, present, and future no-action conditions constitute a threat to wildlife and threatened and endangered (T&E) species. Locations of and potential impacts and enhancements to habitat and wildlife due to removal and capping actions are also evaluated in Section 2 of the BLRA, Section 8 of this RS, and in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

- Transportation issues associated with dredging projects were demonstrated to not be an important issue to the public as part of the demonstration projects at Deposit N, and at Sediment Management Units (SMUs) 56/57. These issues are addressed in the *Sediment Technologies Memorandum* (FS Appendix B), Sections 6 through 9 of the FS, and are in Section 8.3 of this RS.

- Noise associated with a removal project, like transportation, was addressed by the demonstration projects and cited in the same sections above.

- Recreational and scenic impacts are not addressed, per se, in the FS. These are considered to be short-term, temporary impacts that are necessary as part of any remedial operations.

- Landmarks and historic/archeological sites will be addressed as part of the final design process. EPA's FIELDS group has already initiated surveys within the River to determine if there are any submerged sites that may require special consideration during design.

- Governmental experience with sediment removal projects in the Lower Fox River (Deposit N, SMU 56/57) has shown that the energy needs for dredging projects are not extraordinary. While the specific projects cited above are not of the magnitude required by the ROD, they are good indicators of what energy needs will be required for the "scaled up" projects required by the ROD. Also, it should be noted that the ROD-required projects will be accomplished over a period of years so energy needs can be spread out over time. The availability of sufficient energy resources to conduct the ROD-required projects will be considered during the Remedial Design phase of the cleanup project.

- Air quality was again addressed as part of the two demonstration projects. During remediation of the most highly contaminated sediments in the entire Lower Fox River (SMU 56/57), volatilization did not reach a level that posed a risk to human health. The FRG (BBL, 2000) even concluded that: "Although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions and resulting concentrations were found to be relatively small and insignificant relative to human exposure and risk."

- Water quality issues were also addressed in the two demonstration projects and shown to be a minimal issue. Water quality impacts are also addressed in *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits* in this RS.

- Wetlands are addressed within the BLRA, the FS, and in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River* of this RS. It is unclear as to which wetlands the commenters are referring to as being impacted during the implementation of the remedy. Although removal is proposed in shallow water, the RI, BLRA, and FS clearly illustrate that the proposed remediation does not overlap with identified wetlands.

### Reference

BBL, 2000. Major Contaminated Sediment Site Database. Last updated August 1998. Website. http://www.hudsonwatch.com.

## Master Comment 1.4

A commenter stated that a 1 ppm RAL is inappropriate and arbitrary because it was selected without considerations of dredging feasibility, cost, or risk, or reach-specific approaches to cleanup levels.

### *Response*

The selection of the 1 ppm RAL is not arbitrary. In selection of the RAL, WDNR and EPA considered RAOs, model forecasts of the time necessary to achieve risk reduction, the post-remediation SWAC, comparison of the residual concentration to SQTs for human and ecological receptors, as well as sediment volume and PCB mass to be managed as well as the cost. This is discussed in more detail in Section 9.6 of the Proposed Plan.

Multiple RALs were considered for each OU, which include no action and action levels ranging from 0.125, 0.25, 0.5, 1, and 5 ppm. Model forecasts were used to compare the projected outcomes of the remedial alternatives using various action levels with the RAOs, primarily RAOs 2 and 3, which deal with protection of human health and the environment. On the basis of that analysis and to achieve the risk reduction objectives using a consistent action level, 1 ppm was agreed upon as the appropriate RAL.

In OU 1, the time needed to reach the endpoints for risk reduction varies by receptor from less than 1 year to an estimated 29 years. As was pointed out in earlier documents (e.g., the Proposed Plan), the upstream reach achieves risk reduction faster than does the area around the mouth of the River. The SWAC in OU 1 is a measure of the surface (upper 10 cm) concentration and would be 0.19 ppm if all material greater than 1 ppm can be removed. The SWAC value provides a number that can be compared to the SQTs developed in the BLRA. SQTs are estimated concentrations that link risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. A comparison of the SWAC and SQT values shows that there is overlap of the various SQT values for recreational anglers, high-intake fish consumers, and wildlife, and the SWAC values for OU 1.

The 1 ppm action level results in the removal of a significant volume of contaminated sediment and PCB mass from OU 1 at an estimated cost of $66.2 million. Note that this figure does not include the additional cost of $9.9 million for MNR in OU 2, which increases the total cost of the remedy for OUs 1 and 2 to $76.1 million.

Based on the above, WDNR and EPA disagree with the view expressed in this comment. The basis for the selection of the technology and the RAL in the remedy for the Lower Fox River is clearly stated in the Proposed Plan. Feasibility, cost, risk, and reach-specific approaches were all considered and are covered in the RI/FS, BLRA, and the MDR that support the Proposed

Plan. These considerations are also part of the Superfund evaluation process (i.e., the "nine criteria" comparisons and evaluations).

## Master Comment 1.5

Commenters suggested that the Agencies do a better job of citing both legal and health reasons for pursuing this cleanup and make it clear that government has no choice but to enforce the law.

## *Response*

WDNR and EPA believe that health concerns and legal citations are adequately addressed. Human health effects are clearly discussed in both the Executive Summary and the human health portion of the BLRA, as well as Section 6 of the Proposed Plan.

The legal issues do compel that these actions be undertaken. These are from the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) law and the federal National Contingency Plan (NCP) found at 40 CFR Part 300. Action is required at Superfund sites through CERCLA, which is also known as the Superfund law. This is a national program enacted by Congress in 1980. Superfund requires that EPA identify responsible parties or contributors to the contamination. These groups or individuals are known as PRPs, and can include the owners and operators of the facility or property, persons who transported or arranged for waste to be taken to the contaminated site, and waste generators.

CERCLA created a tax on chemical and petroleum businesses, and money collected from the tax went into a large trust fund known as "Superfund." Superfund was created to pay for the cleanup of the country's worst waste disposal and hazardous substances spill sites that endangered human health and/or the environment. The EPA administers Superfund in cooperation with individual states. The WDNR coordinates Wisconsin's involvement in Superfund.

CERCLA does mandate that PRPs are liable for addressing contamination at the site. Through legal action, EPA may pursue cost recovery for any tax dollars spent on remediation.

With a Superfund site, the public often participates through public meetings or by submitting comments on the plans. The public may also be informed through newsletters, direct mailings, or interviews with state/federal agency staff, and other means. All of these methods have been used at the Lower Fox River Site and two technical assistance grants totaling $100,000 have been provided to the Clean Water Action Council (CWAC).

For more information on the federal Superfund Program in Wisconsin, please visit the WDNR web page at:
http://www.dnr.state.wi.us/org/aw/rr/archives/pubs/RR122.pdf.

## Master Comment 1.6

Commenters stated that they would prefer a prompt State-managed remedial action, based on a settlement of claims and defenses with the paper mills, before the issuance of an ROD and without formal NPL listing. These sentiments include the need for long-term cooperation among all entities; that timeliness in commencing cleanup is a key to success and delay is not beneficial; that CERCLA focuses on liability and protecting legal rights; that litigation diverts resources; and settlement will provide greater public confidence in the remedy.

## *Response*

WDNR and EPA agree with the sentiments expressed here concerning the need for timely cleanup, avoiding delays and litigation, and that a negotiated settlement is the preferred method provided the remedial option is protective of human health and the environment. The Agencies also agree with the statement on the CERCLA processes and believe it is important to ensure that the rights of all parties are protected.

The Agencies agree that cooperation among all parties is necessary and desirable to moving the Lower Fox River Site to a better and faster resolution and cleanup. However, the Agencies believe that the Superfund process helps, not hinders, that approach. The focus of CERCLA is protection of human health and the environment through the cleanup and remediation of environmental hazards, not litigation. By going through the CERCLA process, a complete analysis of the nature and extent of the contamination is conducted and the remediation is clearly set forth in the ROD so that the public knows what will be done at the site. If the parties responsible for the contamination choose not to cooperate in the remediation of the site, then CERCLA provides the enforcement tools necessary to compel their action. Thus, while the Agencies agree that cooperation among all interested parties is needed at the Lower Fox River Site, the Agencies believe that the CERCLA Superfund process, from the proposed listing to the ROD, with the possibility of litigation if needed, helps rather than hinders the quick and proper cleanup of the Lower Fox River Site.

## Master Comment 1.7

Commenters suggested that the Agencies should include in the ROD adaptive management and project management approaches for dealing with the complex remediation of the Lower Fox River.

### *Response*

WDNR and EPA are taking a phased approach. The Agencies are issuing an ROD for OUs 1 and 2 at this time and expect to issue an ROD for OUs 3 through 5 at a later time. The Agencies plan to use any "lessons learned" on OUs 1 and 2 for implementing or modifying remedies for OUs 3 through 5.

Consistent with adaptive management and adaptive project management principles, WDNR and EPA have sought to introduce a degree of flexibility into the Lower Fox River ROD, consistent with recent guidance by EPA. On February 12, 2002, Assistant Administrator Marianne Lamont Horinko issued a memorandum entitled "Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites" (Principles). Among other things, that document encourages ROD decisions to adopt an "iterative approach" in a risk-based framework. Specifically, principle number 5 states: "EPA encourages the use of an iterative approach, especially at complex sediment sites." And, further, "At complex sediment sites, site managers should consider the benefits of phasing the remediation." Moreover, the NCP, at 300 CFR § 430(a)(1)(ii), states:

> **Program Management Principles.** EPA generally should consider the following general principles of program management during the remedial process:
>
> (A) Sites should generally be remediated in operable units when…phased analysis and response is necessary or appropriate given the size or complexity of the site…

In adding the "Contingent Remedy" to the ROD (see Section 13.4), and in selecting a remedy for OUs 1 and 2 only, WDNR and EPA have sought to create the ROD flexibility described in the Principles memorandum and the NCP. Such flexibility will allow for "mid-course corrections" in the selected remedy based on what is learned from remedial activities undertaken early in the process.

## 1.3 Applicability of NAS/NRC and 11 Principles

### Master Comment 1.8

Commenters complained that the Agencies have disregarded the key recommendations of the NAS NRC report. The Draft FS does not seriously consider the risks posed by PCB-contaminated sediment left behind at the surface after dredging, the risks posed by PCBs released to the water column during dredging, and the eco-risks on habitat and food web. Commenters further complained that a decision to select the proposed remedy would be arbitrary and capricious and not in accordance with law. Further, another commenter suggested that the Proposed Plan fails to meet NCP criteria and, therefore, was unlawful.

## *Response*

NCP criteria require that the remedy selection process involve the evaluation of alternative remedial actions using the following nine criteria:

- **Threshold Criteria**
  - Overall protection of human health and the environment; and
  - Compliance with applicable or relevant and appropriate requirements (ARARs).
- **Primary Balancing Criteria**
  - Long-term effectiveness and permanence;
  - Reduction of toxicity, mobility, or volume;
  - Short-term effectiveness;
  - Implementability; and
  - Cost.
- **Modifying Criteria**
  - State acceptance; and
  - Community acceptance (40 CFR § 300.430 (e)(9)(iii)).

These nine criteria were evaluated for the Lower Fox River. In addition, the Lower Fox River and Green Bay RI/FS report is consistent with the 11 guiding principles defined by the EPA (EPA, 2002), which are consistent with the NCP criteria and NRC recommendations contained in *A Risk Management Strategy for PCB-contaminated Sediments* (NRC, 2001). Each of the 11 EPA principles and how they were applied to the Lower Fox River and Green Bay RI/FS are fully set forth in *White Paper No. 10 – Applicability of the NRC Recommendations for PCB-Contaminated Sediment Sites and EPA's 11 Contaminated Sediment Management Principles*, and are summarized below.

**Control Sources Early –** Through the WDNR's Wisconsin Pollution Discharge Elimination System (WPDES) program and the discontinued use of PCBs in the production of carbonless copy paper, point source introduction of PCBs into the Lower Fox River has essentially been eliminated.

**Involve the Community Early and Often –** Community involvement has been a critical component of all aspects of this process.

**Coordinate with States, Local Governments, Tribes, and Natural Resource Agencies –** WDNR, EPA, United States Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and the Oneida and Menominee Indian tribes signed a Memorandum of Understanding (MOU) to coordinate early with local governments, tribes, and other Natural

Resource Trustees to ensure that all relevant information and viewpoints are being considered when making remedial decisions.

**Develop and Refine a Conceptual Site Model that Considers Sediment Stability –** The Lower Fox River and Green Bay fate/transport models and food web models (Fox River Food Model [FRFood] and Green Bay Toxics Model [GBTOXe]) are mathematical representations of river hydrodynamics and biota exposure and effect scenarios.

**Use an Iterative Approach in a Risk-Based Framework –** The risk assessment process implemented for the Lower Fox River and Green Bay followed NRC and EPA recommendations by using a flexible, iterative, and tiered approach, which involved risk characterization that began with a screening level assessment, followed by a baseline assessment that incorporated a re-evaluation of potential impacts and other site assumptions.

**Carefully Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models –** The risk assessment for the Lower Fox River and Green Bay discussed uncertainty associated with the supporting site data, temporal and spatial variability, and toxicity and exposure assumptions made during development of the site models.

**Select Site-Specific, Project-Specific, and Sediment-Specific Risk Management Approaches that Will Achieve Risk-Based Goals –** The Lower Fox River and Green Bay FS report does not select a preferred remedy, instead a range of alternatives, action levels, costs, and relative risk reduction are presented.

**Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals –** Endpoints will be compared to residual risk levels over time and achievement of the project RAOs.

**Maximize the Effectiveness of Institutional Controls and Recognize Their Limitations –** Due to elevated PCB levels at the Lower Fox River and Green Bay, WDNR issued consumption advisories for fish and waterfowl in 1977 and 1987, respectively, and Michigan issued fish consumption advisories for Green Bay in 1977.

**Design Remedies to Minimize Short-Term Risks While Achieving Long-Term Protection –** In evaluating potential remedies for the Lower Fox River and Green Bay, short-term risks will be minimized to the extent practicable.

**Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness –** A Model Long-term Monitoring Plan was prepared as part of the FS to ensure that the selected remedy is adequately mitigating risk and achieving project RAOs.

**References**

EPA, 2002. *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites*. OSWER Directive 9285.6-08. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. Drafted October 22, 2001. Signed February 12, 2002.

NRC, 2001. *A Risk Management Strategy for PCB-Contaminated Sediments*. National Research Council, National Academy of Sciences, Committee on Remediation of PCB-Contaminated Sediments. National academy Press, Washington, D.C.

# 1.4 ARARs and TBCs

## Master Comment 1.9

Commenters stated that RAO 1 is inappropriate because the EPA and WDNR determined that state water quality criteria are not ARARs for sediment remediation.

## *Response*

The Agencies disagree with this statement. RAOs are not required to mirror state and federal laws and guidance. If this were the case, then there would be no need for RAOs and environmental agencies would only need to consider ARARs and To be Considered (TBCs).

## Master Comment 1.10

Many comments were received which, in part, challenged the viability of the Proposed Plan based on discharge water quality and quantity concerns. In particular, the comment authors claimed that the dredging recommended in the Proposed Plan was not viable because the quality and quantity of wastewater generated in the dredging process could not comply with water quality standards and associated WPDES permit limits, even using the most advanced wastewater treatment process. The wastewater quantity and quality limitations would, therefore, restrict the allowable wastewater discharge rate, thereby decreasing the allowable dredging rate and increasing the dredge schedule from the 7 years estimated in the Proposed Plan to as much as 37 to 60 years. Based on these assumptions, the comment authors concluded that in-place sediment capping was the only viable alternative for remediation of the Lower Fox River sediment.

## *Response*

In response to these interpretations, WDNR analyzed the assumptions used to support the commenters' conclusions, and performed an evaluation to determine if the expected dredge process wastewater characteristics and volumes would restrict or limit the viability of the Proposed Plan as claimed in the comments. The complete evaluation can be found in *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits*. This analysis confirms that dredge process wastewater quantity and/or quality does not restrict the viability of dredging as recommended in the Proposed Plan and therefore does not solely justify capping. Several shortcomings of the commenter's original analysis were identified that lead to their conclusion including: failure to properly interpret and apply Wisconsin Statutes and Administrative Codes, failure to acknowledge the two permitted discharges from the pilot dredging projects at Deposit N and SMU 56/57, and failure to acknowledge that effluent data from the two dredging projects represents the most representative data for evaluating limitations.

Please also see response to Master Comments 5.52 through 5.60 below.

## Master Comment 1.11

Commenters suggested that the proposed remedy will not comply with location-specific ARARs relating to wetlands, Endangered Species Act (ESA), and Fish and Wildlife Coordination Act.

## *Response*

WDNR believes that it is in full compliance with the Clean Water Act (CWA), the ESA, and the Fish and Wildlife Coordination Act. WDNR will continue to abide by all applicable statutory requirements of these and other laws.

It is unclear as to which wetlands the commenters are referring to as being destroyed during the implementation of the remedy. However, although removal is proposed in shallow water, the RI/BLRA/FS clearly illustrates that the proposed remediation does not overlap with identified wetlands. Further wetland-related issues are addressed in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

Regarding the commenters' concern that: "The RI/FS & PRAP Violate The Fish and Wildlife Coordination Act" they failed to understand the significance of the statement in the Proposed Plan which reads: "Federal, state, and tribal officials subsequently signed an agreement on July 11, 1997, to share their resources in developing a comprehensive cleanup and restoration plan for the Lower Fox River and Green Bay." Indeed, WDNR and EPA are closely coordinating all activities associated with both the remedy selection and implementation as well as Natural Resource Damage Assessment (NRDA). This is clearly illustrated by both the consent decrees reached with Fort James Operating Company and Appleton Papers Inc./NCR Corporation for funding remediation and restoration activities.

# 1.5 Public Participation and Concerns

## Master Comment 1.12

Commenters argued that WDNR and EPA could not issue a ROD based upon the RI/FS because citizens have not been able to comment on all documents because they're still not available for comment.

## *Response*

"The community/public participation activities to support selection of the remedy were conducted in accordance with CERCLA § 117 and the NCP § 300.430(f)(3)." Complete copies of the RI/FS, Proposed Plan, and other related documents have been made available to the public. These have been available at five public repositories in the Fox River Valley as well as being posted on the WDNR's web page for the Lower Fox River (http://www.dnr.state.wi.us/org/water/wm/lowerfox/index.html). In addition, the administrative records for the RI/FS and Proposed Plan are available at the WDNR's offices in Green Bay and in Madison.

The information repositories are located at the Appleton Public Library, Oshkosh Public Library, Brown County Library in Green Bay, Door County Library in Sturgeon Bay, and Oneida Community Library. Five additional locations, at the Kaukauna, Little Chute, Neenah, De Pere, and Wrightstown Public Libraries, still maintain a fact sheet file, although they are no longer information repositories.

EPA awarded a $50,000 Technical Assistance Grant (TAG) to the CWAC in 1999 and another $50,000 grant was provided in 2001. The council has used its TAG to inform the community about the Lower Fox River investigations. To fulfill its obligations, CWAC developed a website, printed flyers and bumper stickers, paid for newspaper advertisements and paid technical advisors to review EPA- and WDNR-generated documents.

WDNR and EPA held numerous public meetings and availability sessions beginning in the summer of 1997 to explain how and why the Site was proposed for the Superfund NPL. In February 1999, a draft RI/FS was released with a 45-day public comment period, which was extended an additional 60 days. Prior to and after the release of the draft RI/FS, WDNR and EPA provided for extensive community and public participation, and kept residents, local government officials, environmental organizations, and other interest groups apprised of the steps of the process. Well-attended public meetings, small group discussions, meetings and presentations for local officials, and informal open houses continued through 2001.

Public meetings and Proposed Plan availability sessions were announced to the public at a press conference on October 5, 2001, and received extensive coverage through television, radio, and newspaper stories. The final RI/FS and Proposed Plan were formally presented at public meetings held on October 29, 2001 in Appleton and October 30, 2001 in Green Bay where oral and written comments were accepted. Additionally, WDNR and EPA mailed meeting reminders and Proposed Plan summaries to the 10,000 names on the Lower Fox River mailing list. Press releases pertaining to the Proposed Plan, comment period, and public meetings were sent to newspapers and television and radio stations throughout the Fox River Valley. Display advertisements announcing the Proposed Plan, comment period, and public meetings were also placed in Green Bay and Appleton newspapers. The presentations, question-and-answer sessions, and all public comments taken at the meetings were recorded and transcribed. The written transcripts of the public meetings are available in the information repositories, the administrative record, and on the WDNR Lower Fox River web page. Approximately 400 people attended.

More than 20 public meetings and availability sessions have been held regarding the project. Cleanup and restoration activities, the status of pilot projects, fish consumption advisories, and the February 1999 draft RI/FS released by WDNR have been among the topics on which these meetings focused. Additionally, over 15 small group and one-on-one interview sessions have been held. Project staff have also made more than 60 presentations to interested organizations and groups. In addition, WDNR, EPA and their intergovernmental partners publish a bimonthly newsletter, the *Fox River Current*, which is mailed to over 10,000 addressees. To date, 23 issues of the *Fox River Current* have been published.

Copies of the various supporting reports and the Proposed Plan were made available to the public during a public comment period that began on October 5, 2001 and concluded on January 22, 2002. Approximately 4,800 written comments were received via letter, fax, and e-mail. A copy of this RS for these comments is attached to the ROD. Newspaper advertisements were placed in the *Green Bay Press Gazette* and the *Appleton Post Crescent* announcing the availability of the Proposed Plan and its supporting documents, and a brief summary of the Proposed Plan in the information repositories. The Proposed Plan, the RI/FS, and other supporting documents containing information upon which the proposed alternative was based were also made available on the WDNR's website.

## Master Comment 1.13

Commenters expressed the view that that the Agencies should consider alternative remediation goals for the Lower Fox River that are protective of human health and the environment. Concerns were raised that local governments were not presented with sufficient information to determine whether the cleanup goal set forth in the Draft FS is the appropriate cleanup goal for the River. They noted that cleanup standards less stringent than that set forth in the Draft FS have been adopted for other PCB sites.

### *Response*

In response to comments received from the public, and from an independent peer review on the 1999 RI/FS, WDNR and EPA required that the FS consider a range of potentially applicable RALs and alternatives. The FS evaluated six RALs (0.125 to 5 ppm and no action) and up to six different options for each reach. Thus, 25 separate alternatives and the supporting information and evaluations were developed for each OU of the River.

The Proposed Plan considered the 1 ppm RAL based on risk, costs, and the CERCLA nine criteria (see response to Master Comment 4.13). Cleanup standards are site-specific; and both less stringent, and more stringent values have been adapted, based on site-specific considerations. These have ranged from as low as 0.25 ppm up to 5 ppm. The RAL of 1 ppm in the Proposed Plan was determined based upon careful consideration of protecting human health and the environment, and balancing that against the CERCLA nine criteria, that also considers cost and community acceptance. The cleanup goal was determined consistent with CERCLA as well as EPA policy and guidance, and consistent with the recent guidance issued by the NRC.

## Master Comment 1.14

Commenters noted that the public participation process must be continued proactively throughout the entire remediation process and follow-up monitoring phase. They said the Agencies need to meet directly with the public in both communities along the River and Bay at least twice yearly during the project, and that active and open public involvement in the design and implementation of the cleanup is crucial to a successful cleanup.

### *Response*

WDNR and EPA are committed to keeping the public informed. WDNR and EPA are issuing a fact sheet and will hold a meeting with the public to discuss the ROD for OUs 1 and 2. As is stated in the current community involvement plan, WDNR and EPA will meet with the public throughout the project’s design, implementation, and monitoring phases.

Furthermore, once a ROD is signed, Superfund requires that community involvement plans be updated. Staff from the Agencies meet with the public to identify concerns and informational needs pertaining to the cleanup. That public involvement and communication plan is currently in preliminary development. WDNR and EPA expect the post-ROD community involvement plan may include regular general public meetings and more focused meetings to address community concerns regarding specific aspects of project activities. The regularity of those meetings will be determined as the plan is developed. Additionally, regular briefings of local governmental and tribal officials may be held.

WDNR and EPA staff will continue to be available to make presentations to interested local organizations and groups. These activities will enable WDNR and EPA to take municipal and community input into consideration during the design, implementation and monitoring phases.

## Master Comment 1.15

Commenters recommended that a River and Bay PCB Remediation Advisory Committee should be created, as an oversight group with no veto power but with the power to force reconsideration and/or appeal upon a majority vote and public interest advocacy.

## *Response*

Through an EPA program called Community Advisory Groups, citizens can meet regularly and stay involved in the cleanup's progress. While the group would not have power to force reconsideration of aspects of the cleanup, it could serve as a focal point for the exchange of information between the Agencies and the community. More information on this program can be found at http://www.epa.gov/superfund/tools/cag.

## Master Comment 1.16

Commenters stated that local governments have a perspective independent from the paper mills, WDNR, and EPA, and wish to have their perspective understood by all other parties.

## *Response*

The Agencies will continue to talk with local government officials to ensure that their perspective is understood throughout the cleanup process.

## Master Comment 1.17

Commenters suggested that public involvement and accessibility should be improved by involving citizens from Door County and the western shore of Green Bay; producing simpler, consistent summaries of the RI/FS; and keeping the process accessible at every step.

## *Response*

Several citizens were interviewed in 1998 and 1999 from these areas. Their input was included in the community involvement plan. They are also part of the 10,000 names on the mailing list for the *Fox River Current* bimonthly government newsletter. One of the Site's five information repositories is at the Door County Library in Sturgeon Bay.

## Master Comment 1.18

Commenters stated that the public would see clear and significant economic benefits of Lower Fox River and Green Bay remediation. Some commenters stated that economic educational materials are necessary. Other commenters stated that the Agencies should articulate the economic benefits of thorough cleanup.

### *Response*

The Agencies agree with these sentiments. It is the Agencies' belief that other sediment remediation projects have also seen economic improvements after completion of sediment cleanup. However, preparation of this type of analysis and educational material is beyond the scope of the RI/FS and ROD.

However, in support of the above, it should be noted that the Wisconsin statutes and the NCP both require that the selected remedy be protective of human health and the environment and the selected remedy fulfills this requirement.

In addition, it is the Agencies' belief that other sediment remediation projects have also seen economic improvements after completion of sediment cleanup. Though preparation of a specific economic analysis and educational material is beyond the scope of the RI/FS and ROD, WDNR and EPA are mindful of the economic consequences on the local economy of a large-scale, multi-year cleanup project in the Fox River Valley. Both Agencies have publicly stated that the selected remedy for the Lower Fox River should not be unnecessarily harmful to the local economy, and it is the Agencies' belief that the remedy selected in the ROD will fulfill this concept.

A project of the magnitude called for in the ROD will bring many jobs and paychecks to the Fox River Valley. While the Agencies have not specifically quantified the economic benefits, certainly many local suppliers of material needed for the remediation will see an increase in orders. To be sure, the remedy called for in the ROD is expensive, but these are dollars that will be spent in the Fox River Valley – on equipment, fuel, supplies, hotels, restaurants, etc. – all of which will have beneficial economic impacts on the Valley. At the conclusion of the cleanup work, a clear, but intangible benefit will be a cleaner River for all citizens of the Valley to enjoy. Increased tourism should result as the Fox River Valley becomes a more attractive destination and the world-class fishery of the River is rehabilitated. The Agencies have reviewed the financial health of the several companies likely to be most impacted financially by the ROD, and have concluded that they can undertake the financing for a project of this magnitude and not be unnecessarily harmed (see *White Paper No. 17 – Financial Assessment of the Fox River Group*).

## Master Comment 1.19

Commenters were concerned that the proposed Lower Fox River cleanup plan would not protect human health and protect the local economy.

## *Response*

See response to Master Comment 1.18 above and Sections 3 and 5 of this RS.

## Master Comment 1.20

Commenters acknowledged that a PCB problem exists and some action is necessary. They then expressed the opinion that the PCB risk and exposure has been overstated and overly generalized. As a result, the Proposed Plan is technically flawed, overbroad, not cost-effective, and likely will not achieve the stated RAOs.

## *Response*

WDNR and EPA disagree with this characterization. In developing the RI/FS, the BLRA, and Proposed Plan, WDNR followed EPA guidance in addition to working closely with EPA. The Agencies believe the remedy selected in the ROD is technically feasible, cost effective, and will achieve the site-specific RAOs.

## Master Comment 1.21

Commenters stated that the extraordinary scope of the Proposed Plan remedy for Little Lake Butte des Morts makes the need for site-specific analysis critical.

## *Response*

WDNR and EPA agree that site-specific analysis is very important. The recommendation in the Proposed Plan for Little Lake Butte des Morts is site-specific for that OU. We have based our decision on the information concerning the degree and extent of the contamination in the RI for Little Lake Butte des Morts, risks were assessed specific to Little Lake Butte des Morts, and technologies and costs were assessed specific to Little Lake Butte des Morts. Based on this individual assessment of the Little Lake Butte des Morts OU, WDNR and EPA selected the remedial option in the ROD.

## Master Comment 1.22

Commenters expressed the need for following an adaptive management approach and recommended that planning should proceed in general accordance with the Proposed Plan guidelines, but with a commitment to apply the principles of adaptive management throughout the process and offered to be involved.

## *Response*

The WDNR and EPA would like to see the continued efforts of the Green Bay RAPSTAC as well as other parties and inform of them of progress made as this project is undertaken. Furthermore, WDNR and EPA also want to be adaptive to the lessons learned as this remedy is implemented. The Superfund process has flexibility built into it. If, during implementation of an alternative, "lessons learned" indicate that the original decision should be modified, this can be readily done under the Superfund process. The administrative approach depends on the extent of the modifications. The potential modifications are as follows:

- **Minor Modification –** No specific documentation required;
- **Significant Modification –** Documented in an "Explanation of Significant Differences;" and
- **Fundamental Modification –** Documented in a "Record of Decision Amendment."

Any new information learned during implementation of dredging or other activities can be readily incorporated into this process, and appropriate adjustments made as needed.

## Master Comment 1.23

Commenters suggested that the Agencies should implement the remedy as soon as possible with maximum public access and stringent government oversight.

## *Response*

Comment noted. The Agencies will, as part of the community involvement plan, attempt to involve and inform the public of ongoing remediation activities as well as governmental oversight actions.

## Master Comment 1.24

A commenter stated that appropriate metrics should be developed to change the remedy if remediation does not progress as expected and that action levels should be developed to be used during and following remedial activities to evaluate the effectiveness of remedial activities.

## *Response*

WDNR and EPA agree that appropriate metrics need to be considered. Flexibility has been incorporated into the ROD. The ROD describes how the Agencies will decide whether cleanup objectives have been met. The process makes it clear that appropriate measurement techniques will be employed, while at the same time allowing for some flexibility in how these standards are measured and whether a protective cleanup standard is achieved.

# 2 Remedial Investigation

## 2.1 Sources of PCBs

### Master Comment 2.1

Commenters stated that the Proposed Plan's PCB loading estimates significantly overstate the total PCB discharge to the Lower Fox River and that WDNR's assumptions result in an overestimation of discharges by the recycling mills.

Other commenters expressed concern that statements on past PCB use in the Fox River Valley as described in the Draft RI and Proposed Plan contain a series of statements about PCB quantities discharged into the River, about the time period during which discharges occurred; and about the parties responsible for these discharges that are unsubstantiated and inappropriate. These statements are based entirely on Draft *Technical Memorandum 2d (TM2d)*.

### *Response*

PCB Load estimates in the RI/FS and the Proposed Plan are based on TM2d, *Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Lower Fox River*. This document acknowledges that the discharge of 313,600 kg of PCBs is an estimate. It acknowledges that number may be high, or it may be low. For the purpose that it was developed, for evaluating the performance of water quality models, it is believed that the estimate is "good enough." The estimate was developed based on work done cooperatively with the PRPs that have been identified for this Site. Multiple opportunities were afforded the PRPs to present facts, data, and comments during the preparation of TM2d. The 1999 revision is the "final" work on this technical memorandum due to the inability of the PRPs to reach consensus on an approach or data to be used, or for them to provide the WDNR an allocation of contribution of PCBs from the discharges. This WDNR approximation is based on a complete review of the data, as well as information presented to WDNR by the PRPs. Please refer to TM2d for more information on how these estimates were calculated.

### Master Comment 2.2

A commenter expressed concern with the Proposed Plan statement that, "Approximately 313,600 kg (690,000 lbs) of PCBs were released to the environment" as a result of the manufacture and de-inking of PCB-containing NCR Paper. The best available information suggests that this estimate, taken from the Draft TM2d, is low due to a number of factors.

## *Response*

As is stated in TM2d, the estimate of 313,600 kg number may be high, or it may be low. However, it is believed that this is an accurate estimate based on work done cooperatively with the PRPs identified for this Site. Multiple opportunities were afforded the PRPs to present facts, data, and comments during the preparation of TM2d. The 1999 revision is the "final" work on this technical memorandum and factors have been considered.

## Master Comment 2.3

Commenters expressed concern with the Proposed Plan statements that "Ninety-eight percent of the total PCBs released into the Lower Fox River had been released by the end of 1971" and "Five facilities contributed over ninety-nine percent of the total PCBs discharged to the river." The concern is that these estimates are inaccurate because they overlook the significant PCB discharges by the boxboard and de-inking mills between 1971 and 1980 due to the use of post-consumer papers containing carbonless copy paper through file clearing activities.

## *Response*

The Agencies agree with the comments as they relate to the exact percentages of the PCB discharges to the system and modifications have been made to the ROD, as necessary. It should be noted that TM2d contains a disclaimer which specifically states that TM2d has not been developed for the purpose of allocating liability. Furthermore, the Agencies do not believe that it is necessary or appropriate to modify the estimates at this time. As is presented above, refinement of the 1999 estimates of discharge are being made by a consultant to the U.S. Departments of Interior and Justice for the purpose of allocation of liability. The PRPs and their consultants have been afforded multiple opportunities to respond to requests for information relating to PCB discharges to this system. However, even if these percentages are slightly off, WDNR and EPA believe that the assertion that the use of TM2d is a good estimate of PCBs discharged from point sources to the Lower Fox River.

## Master Comment 2.4

A commenter expressed concern regarding the statement in the Proposed Plan that, "Approximately 70 percent of the total PCB quantity discharged into the river has migrated into Green Bay." The commenter claimed that the statement is not accurate because it assumes that all discharged PCBs that are not currently in the River must be in Green Bay.

## *Response*

Wording has been modified in the ROD, as necessary. The intent of this statement was to follow through on the finding of the Lake Michigan Mass

Balance Study that up to 70 percent of the PCBs ultimately entering Lake Michigan on an annual basis come from the Lower Fox River.

## Master Comment 2.5

Commenters stated that recent sampling events in Little Lake Butte des Morts Deposit POG identified the presence of a large deposit of woodchips (16,000 cy) with PCB Aroclor 1254 contamination. The RI/FS does not identify this 1254 deposit and therefore has neglected the significant contribution of non-Aroclor 1242 PCBs.

### *Response*

WDNR and EPA agree that PCB Aroclor 1254 is the primary Aroclor detected in the samples collected within the woodchip deposit. However, according to the sampling data provided for the woodchip sampling conducted in 2001, at least four of the nine samples appear to have Aroclor 1242 detections at concentrations ranging from 0.48 to 1.8 ppm. Aroclor 1242 was used in the manufacture of carbonless copy paper as identified in the 2001 Draft RI/FS.

Concerning the source of the 1254 Aroclor contamination, as is pointed out in TM2d, there are numerous sources of PCBs in the Lower Fox River. EPA and WDNR believe that TM2d accounts for most of the contributors of PCBs from paper manufacturing and recycling. Unfortunately, the woodchips and associated Aroclor 1254 were not discovered by any party investigating the River until recently. WDNR and EPA plan to move ahead with further sampling as part of the final remedy design.

Finally, it should be noted that the Aroclor mixture bears little relationship to the calculation of human health risk (i.e., to food chain exposures) in the Lower Fox River. While additional deposits should be considered in the final cleanup decision, 16,000 cy is a relatively small volume compared to the entire volume considered for remediation in OU 1.

## Master Comment 2.6

Comments were offered that claim that over the last 11 years (1989–2001), water column PCB concentrations declined at a rate where concentration half-lives are 6.8 years at the De Pere dam and 9.0 years at the mouth. The authors also claim these rates are consistent with declines in PCB concentrations in fish tissue and sediment throughout the River in general.

### *Response*

Similar points have been raised for Little Lake Butte des Morts and have been addressed in the response to Master Comment 2.16. The underlying issue is that the sampling and analysis methods in 1998 and 2000/2001 were sufficiently different from the previous efforts so that data comparability was not assured. Therefore, it is not possible to determine how much of the projected decline is due to changes in water concentrations versus how much might be due to very different sampling and analytical methods.

The sampling and analysis methods in 1998 and 2000/2001 were sufficiently different from the previous efforts so that data comparability was not assured. It is not possible to determine how much of the projected decline is due to changes in water concentrations versus how much might be due to different sampling and analytical methods.

### Master Comment 2.7

A comment was provided which asserts that the characterization of the microcapsules used to make NCR Paper as being fragile is incorrect. The comment cites a report which characterizes the microcapsules as being "considered essentially stable under conditions typically encountered in the use of secondary fiber."

### *Response*

The comment is noted, and if necessary, this editorial change will be made in subsequent documents. This term was not included in the ROD in the description on NCR paper.

### Master Comment 2.8

The Proposed Plan states that the PCB-containing "emulsion was sold to Appleton Coated Papers who produced the coated paper in Appleton, Wisconsin." A significant percentage of the emulsion was sold and used elsewhere, particularly by Mead Corporation in Ohio.

### *Response*

See response to Master Comment 2.1. Appropriate editorial modifications will be made in the ROD, as necessary.

## 2.2 Aroclor 1242 vs. 1254

### Master Comment 2.9

Commenters offered that the recent sampling in Little Lake Butte des Morts proves that there is at least one other source of PCBs at the Site unrelated to the recycling of NCR paper. The authors offer that other sources of the recently found small deposit of woodchips containing primarily Aroclor 1254 and 1260 could be capacitors, transformers, hydraulic fluids, rubbers, adhesives, and wax.

### *Response*

There is general agreement that PCB Aroclor 1254 is the primary Aroclor detected in the samples collected within the woodchip deposit in Little Lake Butte des Morts. However, according to the sampling data provided by CH2M HILL for the woodchip sampling conducted in 2001, the Aroclor used in carbonless paper, Aroclor 1242 is also detected. However, this information by itself does not conclusively suggest additional sources. The commenters must also recognize that three of the sources they identified, capacitors, transformers, and hydraulic fluid, are also basic components of their own papermaking equipment.

WDNR and EPA have never claimed that all of the PRPs have been identified. The Agencies will review and consider any additional information provided that assists in identification of additional responsible parties.

## 2.3 Time Trends Analysis

### Master Comment 2.10

Commenters took issue with the comprehensive time trends analysis conducted for the RI. They argue that there are declines in PCB concentrations in fish tissue, sediments, and water that are not used or improperly applied in the RI/FS and Proposed Plan. Their analysis is based on two papers submitted: *BB&L Report on PCB Trends in Fish from the Lower Fox River* (the "BBL Report") and *Time Trends in PCB Concentrations in Sediment and Fish, Lower Fox River, Wisconsin* by Dr. Paul Switzer.

### *Response*

As stated in *White Paper No. 1 – Time Trends Analysis* was collaborated upon by three eminent biostatisticians: Dr. Nayak Polissar (Ph.D. from Princeton University), Dr. Kevin Cain (Ph.D. from Harvard University), and Dr. Thomas Lumley (Ph.D. from University of Washington). All three have published extensively in human health toxicological and epidemiological studies, and are affiliated with the Department of Biostatistics at the University of Washington. Their curriculum vitae are set forth as an attachment to *White Paper No. 1 – Time Trends Analysis*. Specific comments to the methods employed in the TTA are covered in *White Paper No. 1 – Time Trends Analysis*.

Comments relating to alleged declines in water column concentrations of PCBs are discussed in Master Comment 2.16.

### Master Comment 2.11

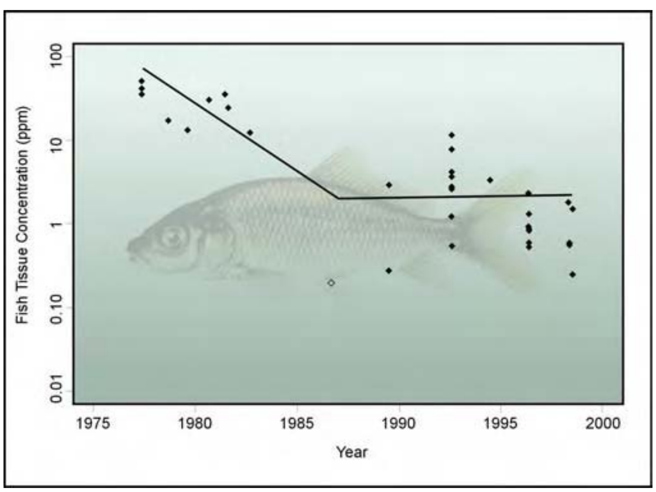
The commenters contend that PCB concentrations in fish tissue are continuing to show decline within the Lower Fox River. They dispute the statistical trends analysis conducted for the RI that showed a leveling off of fish tissue concentrations (the “breakpoint analysis”). They further argue that there is no apparent reason for the breakpoint, that the RI used an inappropriate statistical model, did not make the best use of the available data, and that a simple mathematical representation of the data shows a long-term, consistent downward trend.

## *Response*

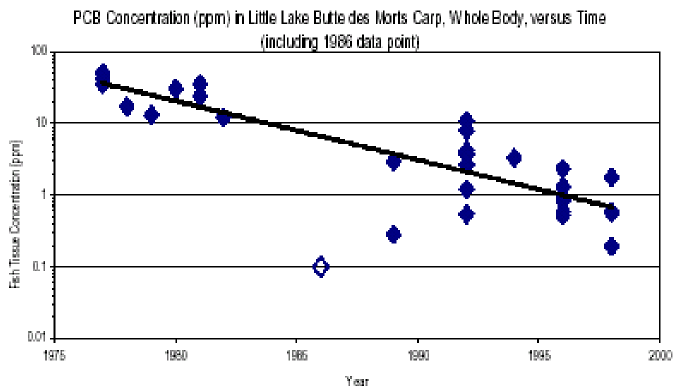
WDNR and EPA believe that fish tissue concentrations have not continued in a downward trend at the rate suggested by the commenters. Furthermore, the analysis conducted for the RI/FS suggests that in many cases, the rate of change has slowed to unacceptably slow levels, or in some cases stabilized and show no change at all.

The central dispute raised by these comments can be seen in the differing interpretation of changes in fish tissue concentrations in the two graphics below. Figure 1, from the Proposed Plan, shows that carp PCB tissue concentrations in OU 1 decline up to a point where a statistically significant “breakpoint” is observed, and that the change in the rate of decline from that point in time is essentially flat. As presented in the TTA, the breakpoint for that species in that reach of the River appears to occur around the mid-1980s. Figure 2 shows the direct-line comparison, using the same data, presented by the FRG’s consultant, BBL, which suggests a steady state and continuing decline. This was also observed for several other species in OUs 1 and 4.

## Figure 1 Carp PCB Tissue Concentrations in OU 1



## Figure 2 Carp PCB Tissue Concentrations in OU 1 Direct-Line Comparison




The TTA presented an analysis of trends in PCB concentrations for fish throughout the River and southern Green Bay. The analysis demonstrated that the rate of decline in fish tissue concentrations observed through the 1970s changed. Several important fish species, including carp, perch, and walleye, show statistically significant slowing of the decline rate, with a breakpoint occurring in the trend in the early to mid-1980s. Even where decline was noted, WDNR and EPA believe that the fish tissue concentrations will remain at concentrations above acceptable levels for some time to come.

As pointed out in the comment response above, the FRG retained Dr. Switzer to critique the work conducted on the TTA. While there are issues raised relating to the choice of model and use of data (discussed in more detail below and in *White Paper No. 1 – Time Trends Analysis*), the fundamental point raised in Dr. Switzer's review is that there is "no identifiable physical reason for a breakpoint and the time series are relatively short." Without being supplied other detailed documentation concerning the Lower Fox River, Dr. Switzer provides a thoughtful critique of the methodology, proposes alternate models and approaches that may be taken, but is not engaged to conduct any of the work proposed. The apparent approach taken in the FRG's comments was to have Dr. Switzer critique the statistical methods in the TTA, and then offer an alternative, simplistic model presented by the FRG's consultant, BBL.

When examining the main tenant of Dr. Switzer's critique, there is a readily identifiable physical reason for a breakpoint. The changes in fish tissue concentrations is observed to occur at that period of time when the mass of PCBs released by direct discharge by the paper mills falls below the steady-state releases of PCBs from sediments. In other words, fish tissue concentrations respond to the diminishing PCB inputs to the River by paper mill discharge, up until the point where the direct release is lower than the sediment release. At that point in time, fish tissue concentrations reflect exposure to sediment releases, and are subject to decline only at the rates at which sediment PCB concentrations decline.

*TM2d: Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Lower Fox River Point Sources* (WDNR, 1999) (TM2d) documents the direct discharges of PCBs from point sources between 1954 and 1997. Table 1 shows a compilation of data compiled in that document for OU 1, and a summary of all direct PCB discharges to the River. Within all reaches of the River, TM2d documents that while direct PCB discharges dropped off significantly in 1971, there were continuing discharges of PCBs up through 1997. While between 1971 and 1972 direct discharges dropped by one order of magnitude, there were continuing inputs at or exceeding 200 pounds annually from the paper mills. The 1989/1990 Mass Balance Study (WDNR, 1995) documented that direct measures of PCBs taken at the Appleton dam measured 143 pounds of PCB discharges in 1989, at a time when direct discharges were less than 2 pounds annually. Thus, a readily identifiable physical reason for a breakpoint in the fish tissue concentration would occur around 1978.

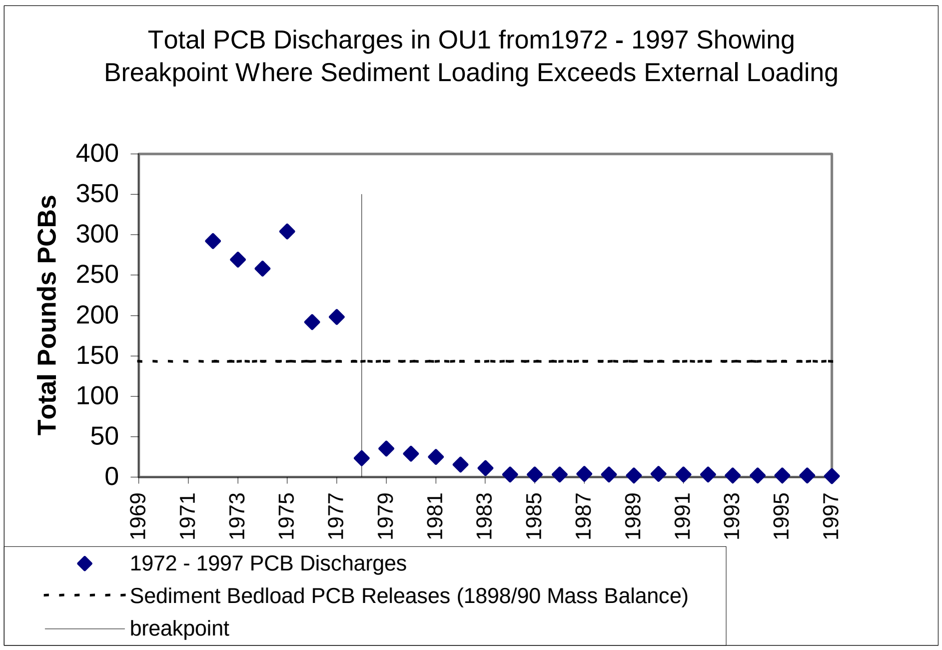
The relatively constant, or in some cases increasing trend observed, is related to source control of direct inputs of PCBs through wastewater discharges, with the continuing, constant source now being the PCBs in the sediments. A similar finding was observed on the Hudson River after the leakage of unweathered PCB oil from the vicinity of the GE Hudson Falls facility had largely been controlled (EPA, 2002).

**Table 1 Total Discharges of PCBs in OU 1, 1954 through 1997 (Data adapted from *Technical Memorandum 2d*, Appendix D)**

| Year | Direct PCB Releases in OU 1 | | | |
|---|---|---|---|---|
| | P.H. Glatfelter Discharge | P.H. Glatfelter Landfill | NM POTW/ Wisconsin Tissue | Total OU 1 PCB Discharges |
| 1954 | 288 | 48 | 110 | 446 |
| 1955 | 1,268 | 190 | 542 | 2,000 |
| 1956 | 2,293 | 326 | 709 | 3,328 |
| 1957 | 2,264 | 390 | 938 | 3,592 |
| 1958 | 4,032 | 545 | 1,171 | 5,748 |
| 1959 | 4,868 | 730 | 1,982 | 7,580 |
| 1960 | 4,870 | 730 | 1,966 | 7,566 |
| 1961 | 7,246 | 1,087 | 2,096 | 10,429 |
| 1962 | 8,687 | 1,303 | 2,490 | 12,480 |
| 1963 | 10,767 | 1,615 | 2,419 | 14,801 |
| 1964 | 11,996 | 1,799 | 2,434 | 16,229 |
| 1965 | 12,635 | 1,895 | 5,641 | 20,171 |
| 1966 | 16,265 | 2,439 | 7,676 | 26,380 |
| 1967 | 14,502 | 2,175 | 5,820 | 22,497 |
| 1968 | 19,048 | 2,857 | 8,635 | 30,540 |
| 1969 | 22,650 | 3,397 | 11,297 | 37,344 |
| 1970 | 14,947 | 2,242 | 10,692 | 27,881 |
| 1971 | 2,875 | 431 | 1,750 | 5,056 |
| 1972 | 241 | 36 | 15 | 292 |
| 1973 | 234 | 35 | 0.1 | 269.1 |
| 1974 | 223 | 33 | 2 | 258 |
| 1975 | 263 | 39 | 2 | 304 |
| 1976 | 191 | 0 | 1 | 192 |
| 1977 | 198 | 0 | 0.3 | 198.3 |
| 1978 | 23 | 0 | 0.3 | 23.3 |
| 1979 | 35 | 0 | 0.2 | 35.2 |
| 1980 | 29 | 0 | 0.1 | 29.1 |
| 1981 | 25 | 0 | 0.1 | 25.1 |
| 1982 | 15 | 0 | 0.3 | 15.3 |
| 1983 | 11 | 0 | 0.1 | 11.1 |
| 1984 | 3 | 0 | 0.1 | 3.1 |
| 1985 | 3 | 0 | 0.1 | 3.1 |
| 1986 | 3 | 0 | 0.1 | 3.1 |
| 1987 | 4 | 0 | 0.1 | 4.1 |
| 1988 | 3 | 0 | 0 | 3 |
| 1989 | 2 | 0 | 0 | 2 |
| 1990 | 4 | 0 | 0 | 4 |
| 1991 | 3 | 0 | 0 | 3 |
| 1992 | 3 | 0 | 0 | 3 |
| 1993 | 2 | 0 | 0 | 2 |
| 1994 | 2 | 0 | 0 | 2 |
| 1995 | 2 | 0 | 0 | 2 |
| 1996 | 2 | 0 | 0 | 2 |
| 1997 | 1 | 0 | 0 | 1 |

Figure 3 represents this graphically for the period of 1972 to 1997 in OU 1. Prior to 1978, direct discharge releases still exceeded those PCB loads documented by the 1989/1990 Mass Balance Study, which is shown as the hatched line at 143 pounds annually. In fact, the exposure concentrations seen by fish in OU 1 prior to 1978 would have been a combination of both the direct and sediment PCBs. This trend is typical of the entire River, although the data in TM2d suggest that greater direct loads were still contributed into OU 4 into the mid-1980s.

## Figure 3 Total PCB Discharges in OU 1 from 1972 to 1997




This above does not, however, necessarily imply that the break will occur exactly in 1978, and in fact, most of the breakpoints shown in the TTA come in the early to mid-1980s. The TTA acknowledges that the breakpoints are "best fit" models, and are not precise estimates of the year in which change occurs. In the case of the carp example shown above for OU 1, there are very few data points for concentrations between 1982 and 1986. Equally important in evaluating the breakpoint is the biology of the fish themselves; fish exposed in the late 1970s will continue to be present in later years. For example, the usual longevity of carp is 9 to 15 years (maximum observed is 47 years), while walleye average 7 years (Becker, 1983). Thus, carp exposed in 1971 when as much as 28,000 pounds of PCBs were discharged into the River would still be in the system in the mid-1980s.

The issues relating to selection of models, use of data, and responses to specific technical issues raised are detailed in *White Paper No. 1 – Time Trends Analysis*.

### References

Becker, G. 1983. *Fishes of Wisconsin*. The University of Wisconsin Press. Madison, Wisconsin.

EPA, 2002. *Trends in PCB Concentrations in Fish in the Upper Hudson River, White Paper 312627, Responsiveness Summary: Hudson River PCBs Site Record of Decision, January 2002*. Prepared for the United States Environmental Protection Agency and the United States Army Corps of Engineers, Kansas City District by TAMS Consultants.

WDNR, 1995. *A Deterministic PCB Transport Model for the Lower Fox River between Lake Winnebago and De Pere, Wisconsin*. PUBL WR 389-95. Wisconsin Department of Natural Resources. Madison, Wisconsin.

WDNR, 1999. *Lower Fox River and Green Bay PCB Fate and Transport Model Evaluation Technical Memorandum 2d: Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Lower Fox River Point Sources*. Wisconsin Department of Natural Resources, Madison, Wisconsin. Revised February 23.

## Master Comment 2.12

Commenters suggested that PCB concentrations are declining in surface sediments at a rate that supports a natural attenuation alternative within the River. The commenters praise the analysis taken in the TTA, stating that "…the analysis of surface sediment PCB trends by MWL [sic] gives a meaningful depiction of changing PCB concentrations in the active layer…" Concerns were raised that the Proposed Plan relies not on the analysis done in the TTA, but on the separate analysis done as part of the documentation for the Whole Lower Fox River Model.

## *Response*

WDNR and EPA agree that surface sediment concentrations over time have slowly declined, on average. An important element of the TTA is that while the estimated annual compound percent increase in PCB levels calculated for each deposit show general decline, in many cases the upper bound of the 95 percent Confidence Interval show that concentrations could be increasing. In addition, the stability of PCBs that are currently buried in the sediment cannot be assured indefinitely. Sediment conditions in OUs 1 through 3 are a result of and dependent upon maintenance of the current dam and lock system indefinitely. Changes in lake levels are resulting in increasing scour to sediments in OU 4 (LTI, 2002). Lower Lake Michigan elevations are expected through this century as a result of changes to global climate (EPA, 2000). Thus, it is the position of both WDNR and EPA that the sediments of the Lower Fox River do not represent a secure location for the long-term storage of PCBs.

An excellent example of the need to consider all data are new data submitted with public response for OU 1. As documented in *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples*, these data collected in 2001 and 2002 do not support the position taken by the companies that surface sediment concentrations are decreasing within OU 1. An analysis of those data clearly show that in some cases concentrations are lower, and in others higher. For example, within deposits A/B, C, and POG, higher sediment concentrations were measured than had ever been previously reported within the RI/FS. This is especially true in deposits A and POG, where six new stations exceeded 50 ppm, and one station in Deposit POG with a surface concentration of 360 ppm. Samples collected in Deposit E, on the other hand, suggest that the single high concentration of 45.9 ppm collected in 1994 may now be under 10 cm of newly deposited sediment. This combination of lower and higher observations suggest that in spite of best efforts on all parties, sampling variability may result in decreasing or increasing trends. Furthermore, the additional data submitted still show that concentrations in OU 1 exceed the RAL of 1 ppm, and thus constitute an unacceptable risk to human health and the environment.

### References

EPA, 2000. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, Great Lakes – A Summary by the Great Lakes Regional Assessment Group for the U.S. Global Change Research Program*. United States Environmental Protection Agency, Office of Research and Development, Global Research Program. October.

LTI, 2002. *Measurement of Burial Rates and Mixing Depths Using High Resolution Radioisotope Cores in the Lower Fox River*. In: *Comments of the Fox River Group on the Wisconsin Department of Natural Resources' Draft Remedial Investigation, Draft Feasibility Study, Baseline Human Health and Ecological Risk Assessment, and Proposed Remedial Action Plan. Appendix 10*. Prepared by Limno-Tech, Inc., Ann Arbor, Michigan.

# 2.4 Validity of Interpolated PCB Maps

## Master Comment 2.13

Commenters suggest that WDNR’s estimates of PCB mass and sediment volume are overestimates. The basis for this claim is that errors in the interpolation method led to high PCB values being interpolated at depth in non-detect areas, resulting in overall high bias. Thus, as a result, WDNR’s PCB interpolations use physically unrealistic parameters for their inverse-distance-weighing (IDW) interpolation scheme. In support of this claim, the commenters suggest that WDNR failed to incorporate into the interpolation sediment core data that show PCB non-detect values at depth, making it possible for high PCB concentrations to be interpolated into areas where existing data show the concentrations to be at or below the detection limit. These errors lead to overestimation of the size of hot spot areas and exaggeration of PCB mass at depth.

### *Response*

The comment identifies a technical oversight in the interpolations of PCB mass and contaminated sediment volume in the River reach occupied by SMUs 56 through 73 only. Department staff revisited these estimates, determined there is 17 percent difference (reduction) in PCB mass in the above-mentioned SMUs; 12 percent of the total PCB mass in the entire segment of OU 4 downstream of the Fort James turning basin. Because the surface areas of the SMUs in question are small compared to those upstream, the flux ratio of PCBs to the water column is small enough that these at-depth PCB volume differences will have minimal affect on the conclusion reached for OU 4.

## 2.5 Evaluation Based on New Little Lake Butte des Morts Data

### Master Comment 2.14

Commenters presented data that they suggest negates the PCB interpolated bed maps presented in the RI/FS and the remedial actions for OU 1 in the Proposed Plan. New sediment data were submitted as part of the response period with submittals from both P.H. Glatfelter Company and WTM1. These data were the result of sampling events undertaken by Blasland, Bouck & Lee (BBL) on behalf of the P.H. Glatfelter Company, and by CH2M HILL for WTMI. They further argue that these new data show relatively “low” levels of PCBs, specifically within Deposit E, and that these data also demonstrate that natural attenuation is occurring within OU 1.

### *Response*

WDNR and EPA believe that the supplemental data submitted for OU 1 in fact support the remedial action. The data provided during the comment period consisted as either hard copy in the companies’ respective submittal, or as part of the FoxView database submitted with the FRG’s response. None of the supporting quality assurance/quality control (QA/QC) information was submitted during the response period. However, WDNR requested full data packages after the public comment period from both submitters in order to evaluate the data for the final FS, this RS, and for the ROD. Nevertheless, the packages were assessed for QA/QC conformance with the rules established for the Lower Fox River RI/FS, documented in the *Data Management Summary Report: Fox River Remedial Investigation/Feasibility Study* appendix to the RI. The evaluation of the new OU 1 data may be found in the *Addendum to the Data Management Report* and in *White Paper No. 14 –*

*wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, and Proposed Remedial Action Plan*.

A complete analysis of the new data relative to the bed maps and conclusions of the Draft RI/FS may be found in *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples*. The QA/QC'd data were plotted over the RI PCB-interpolated bed maps for OU 1. Based on the evaluation, the following conclusions were evident:

- Within the surface sediments (0 to 10 cm), most of the area within Little Lake Butte des Morts exceeds the 1 ppm action level. This was, and remains true for the largest deposits A, B, POG, and E. The surface-weighted average concentration is not altered by these new data.

- Higher surface concentrations of total PCBs are reported for deposits A/B, C, and POG. Concentrations of PCBs exceeded 50 ppm in deposits A and POG, where the RI had placed those at between 10 and 50 ppm.

- The TSCA PCB threshold of 50 ppm is exceeded for several of the new stations collected at deposits A and POG. This includes one of the highest PCB concentrations ever measured in Little Lake Butte des Morts at Deposit POG of 385 ppm. At Deposit POG, TSCA material is found as deep as the 100- to 150-cm profile. This will impact the proposed remedy for these deposits in that TSCA handling and disposal requirements were not included in the FS for Deposit POG.

- The new data suggest that Deposit E surface sediments are relatively uniform in concentration, between 1 and 5 ppm. The bed maps within the RI show an area of total PCBs exceeding 10 ppm. The interpolation was based upon a single data point of approximately 46 ppm collected in 1994. A similar level was reported in the new data, but it now appears to be just below 10 cm. The supplemental data collected within that same area are all less than 5 ppm, but are all still greater than the RAL of 1 ppm.

- PCB concentrations exceeding the RAL for some deposits may be less, or more than estimated in the RI/FS. For example, PCB concentrations at Deposit A exceed the RAL through the 30-cm depth profile. Within the RI grid maps, PCB concentrations requiring remediation to a depth of cut of 100 cm were found; the supplemental data show PCB concentrations of less than 0.05 ppm. By contrast, PCBs exceeding the RAL are deeper than included in the RI/FS for deposits POG (150 cm) and E (100 cm).

The additional data submitted on behalf of P.H. Glatfelter Company and WTMI generally support the conclusion of the RI/FS and the Proposed Plan. Surface sediments within OU 1 exceed the RAL of 1 ppm. The Proposed Plan-defined remedial actions at deposits A/B, C, POG, and E; these data support that decision. These new data do suggest that the final remedial footprints, both the horizontal and vertical profile, may be refined in the final design. The horizontal footprint for deposits A/B, C, and POG could be drawn larger than the existing bed maps indicate, whereas Deposit E may in fact represent a smaller area than defined in the RI. Depth of removal may be refined as well; the data suggesting that a shallower cut may be needed at deposits A/B and C, but deeper at deposits POG and E.

These new data do not support the position taken by the companies that surface sediment concentrations are decreasing within Little Lake Butte des Morts. A closer look at those data, relative to the bed maps, suggests that in some cases concentrations are lower, and in others higher. For example, within deposits A/B, C, and POG, higher sediment concentrations were measured than had ever been previously reported within the RI/FS. This is especially true in deposits A and POG, where six new stations exceeded 50 ppm, and one station in Deposit POG with a surface concentration of 360 ppm. Samples collected in Deposit E, on the other hand, are lower than the single high concentration of about 46 ppm collected in 1994. This combination of lower and higher observations suggest that this is more an issue of sampling variability, and not decreasing or increasing trends.

## Master Comment 2.15

Commenters stated that the stability of much of Little Lake Butte des Morts' sediment bed prevents the reach's sediments from posing significant risk to human or ecological receptors. The reach does not pose a significant risk to local or downstream human or ecological receptors arising from erosion-generated resuspension and transport.

## *Response*

Regardless of the apparent overall depositional nature of OU 1, there are areas where surface sediment concentrations have not decreased over the study period (Deposit A and portions of Deposit POG). Even with a lack of significant scour events, sediments in these areas are still acting as a source for the transport of PCBs. The fact that this transport occurs means that this reach does indeed pose a risk to downstream human or ecological receptors. In addition, *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples* contains a relevant discussion on this topic.

# 2.6 Scour and Hydrology

## Master Comment 2.16

Several commenters suggested that PCB transport from the Little Lake Butte des Morts sediments is small and is approaching levels similar to those entering from Lake Winnebago. Commenters use this observation to suggest that Little Lake Butte des Morts sediments are no more of a contributor to PCB levels in the water column than Lake Winnebago, RAOs 1 and 4 can not be attained, and Little Lake Butte des Morts sediments are stable. The commenters support their claim of Little Lake Butte des Morts sediment bed stability with the inference that the 2000/2001 TSS data for Little Lake Butte des Morts show that PCB transport does not increase during high-flow events due to increased sediment scour and that *Technical Memorandum 5d* (TM5d) indicates this will continue, essentially forever.

## *Response*

The premise for these claims is based on information presented on RI Figure 5-16 and in Table 5-20. However, the RI gives an inaccurate picture of the PCB transport into and out of Little Lake Butte des Morts. Modifications have been made to the final version of the RI to correct calculation errors and to add needed qualifiers to better clarify what is known regarding PCB transport out of Lake Winnebago. The Green Bay Mass Balance Study (GBMBS) (WDNR, 1995) clearly shows that, while loads from Lake Winnebago were too low to be accurately quantified with the sampling methods used, upper bounds calculations showed the loads were insignificant compared to the loads in the Lower Fox River at Appleton.

Data collected since the GBMBS collected by the FRG (BBL, 1999; LTI, 2002) do not have limits of detection (LODs) low enough to improve on the mass estimates from Lake Winnebago. Field equipment blanks from the FRG 1998 (BBL, 1999) sampling event are all non-detects with LODs ranging up to 200 nanograms per liter (ng/L). Similarly, all the samples collected in Little Lake Butte des Morts ranged only up to 34 ng/L, illustrating similar limitations with this set of data as the GBMBS (WDNR, 1995). The 2000/2001 data is less clear due to lower measured concentrations resulting from a combination of changes in the River and much cruder sampling and analysis techniques that had much higher LODs. In the 2000/2001 data, all samples from Neenah and Menasha were non-detects with LODs higher than the 1989/1990 field blanks so nothing was added to our knowledge about PCB loads from Lake Winnebago. The high LODs also cause significant uncertainties in the concentration measured at Appleton. When detected, however, the concentrations at Appleton were still a significant fraction of the concentrations seen at the De Pere dam (Tables 2-4 and 2-5 in LTI, 2002). The LTI 2002 report also failed to discuss how field equipment blanks were considered in their concentration data and loading calculations.

It is possible that water quality concentrations leaving Lake Winnebago exceed water quality criterion, but the available data is not sufficient to accurately determine if the criteria are exceeded or by how much. The 1989/1990 study measured values in the Neenah Channel were of the same magnitude of the field blanks so the actual concentrations coming from Lake Winnebago are not known. The GBMBS showed the upper bound on the average concentration was around 2 ng/L, but the value could be a lot less; the techniques were not clean enough to tell. No data collected since the GBMB has LODs low enough to improve on this estimate. Thus, the more recent sampling efforts by the FRG also cannot support the claim that loads from Lake Winnebago are a significant fraction of the loads seen at Appleton or that RAOs 1 and 4 cannot be achieved.

The lack of increased TSS at Appleton during events does not mean the PCBs in the Little Lake Butte des Morts sediment are isolated from the water column. There was significant transport of PCBs from the sediment to the water column during the 1989/1990 study and the rate varied largely as a function of time of year or water temperature. While PCB concentrations do not seem to increase during high flows, they do not decrease either. Therefore, more PCB mass must be coming from the sediment during high-flow periods to keep the concentrations relatively constant. The conclusion remains that Little Lake Butte des Morts sediment continues to be a significant source of PCBs, which contributes to the overall load in the system and the corresponding risk.

Regarding the commenters' assertion that TM5d supports their claim of a stable sediment bed in Little Lake Butte des Morts, WDNR and EPA disagree with points made in the body of the comment on the effectiveness of Deposit E as a sediment trap and the degree to which PCBs in the sediment are isolated from the water column in spite of the low resuspension from Deposit E. Deposit E is not an effective sediment trap in terms of its ability to accumulate a significant fraction of the solids in the River. A significant fraction of the solids in the Little Lake Butte des Morts water column is algae with very little settling occurring. The GBMBS (WDNR, 1995) shows about one-third of the PCB mass in the water column becomes dissolved and a part of the particulate portion partitions to algae and other slow-settling solids.

### References

BBL, 1999. *Natural Attenuation Assessment of the Fox River*. Prepared for The Fox River Group by Blasland, Bouck & Lee. April.

LTI, 2002. Measurement of Burial Rates and Mixing Depths Using High Resolution Radioisotope Cores in the Lower Fox River. In: *Comments of the Fox River Group on the Wisconsin Department of Natural Resources' Draft Remedial Investigation, Draft Feasibility Study, Baseline Human Health and Ecological Risk Assessment, and Proposed Remedial Action Plan*. Appendix 10. Prepared by Limno-Tech, Inc., Ann Arbor, Michigan.

WDNR, 1995. *A Deterministic PCB Transport Model for the Lower Fox River between Lake Winnebago and De Pere, Wisconsin*. PUBL WR 389-95. Wisconsin Department of Natural Resources. Madison, Wisconsin.

## Master Comment 2.17

Some commenters suggested the RI/FS is based upon confusing and contradictory information regarding the scouring and the transport of River sediments. They contend that the Proposed Plan and draft FS suggest that the entire Lower Fox River including Little Lake Butte des Morts is dynamic and that PCBs buried anywhere in the Lower Fox River can become uncovered and suspended. They offer that site-specific data indicate that Little Lake Butte des Morts' sediment bed is stable, not dynamic as suggested TM2g as it is an impoundment. They believe the additional analysis they provided show that many deposits are, in fact, not highly dynamic or erosional, and are areas where PCBs are buried and will not be eroded even in a 100-year storm event.

## *Response*

The WDNR agrees that some statements in Sections 4.2, 5.2, and 5.3 of the Proposed Plan regarding suspension and scour of sediments throughout the River are probably too general and not as valid for Little Lake Butte des Morts as for the lower segments of the River. Section 5.3, for example, was written as an attempt to summarize the hydrodynamic characteristics of the Lower Fox River, with its principal point being that the sediments, in general, are dynamic and do not function in discrete layers. Discussion of the work of TM2g was included to add credence to the generalized statement that "scouring of the sediment bed plays a significant role in the quantity of sediment and contaminants transported through the river system." To avoid confusion, any similar use of this discussion in the ROD will clarify the locational specifics of the TM2g study.

Regarding the use of water column data to support the claim that the sediment bed of Little Lake Butte des Morts is stable and not dynamic: a lack of increase in TSS during high flows may indicate minimal erosion of the sediment bed, but is not direct evidence that PCBs in sediments are isolated from the water column, as exemplified by the 1989/1990 water column data. Because PCB concentrations are not decreasing during varied flows, PCB-laden sediment must be acting as a source during higher flow events in order for these concentrations to remain relatively constant.

Regardless of the apparent overall depositional nature of OU 1, there are areas where surface sediment concentrations have not decreased over the study period (Deposit A and portions of Deposit POG). Even with a lack of significant scour events, sediments in these areas are still acting as a source for the transport of PCBs. It is for this reason that the WDNR has put forth and still maintains the decision of dredging the top 100 cm of this material, thereby removing some 97 percent of the mass of PCBs from the environment.

The reader is referred to the response to Master Comment 2.16 for additional elaboration of these additional studies.

## Master Comment 2.18

A commenter indicated there are four direct lines of evidence behind the depositional nature of the Lower Fox River including the need for dredging, TSS decrease as the River flows downstream, PCB concentration gradients in sediment cores, and radioisotope patterns in thin sections of sediment cores.

## *Response*

WDNR and EPA do not disagree that some deposition takes place in the Lower Fox River. However, the hydrodynamics of the Lower Fox River are very complex. Monitoring of the River indicates that the River is both erosional and depositional over time. Monitoring results indicate that without continued point sources contributing PCBs to the system, the continued presence of PCBs in the surface sediment layers is the result of erosion, transport, and redeposition of PCB-contaminated sediment.

## Master Comment 2.19

A commenter offered that the 1977 data are uncertain due to rudimentary methods of vessel positioning (e.g., right angle prism, tag lines). TM2g of the MDR shows transect comparisons were 90 feet off, so 14-foot elevation change is untrue.

## *Response*

As discussed in earlier responses, the Proposed Plan claim of 14 feet of scour is not based on the interpretations of Transect 1A of TM2g, but rather on the interpretations of the FIELDS map documents.

The 14-foot elevation change came from an interpretation of EPA FIELDS' interpolated maps, (i.e., a comparison of 1999 interpolated sediment elevation values with 2000 interpolated sediment elevation values). The most significant comparisons of sediment elevation differences over time are not unique instances of gains or losses in elevation, but rather the spatial and dynamic nature of these differences.

As stated in TM2g, the 1990 transect for Figure 1A is an average of the two bounding range lines. The possible error associated with this averaging is clearly addressed in the "Uncertainty" section of the document. Even if the 1990 transect is ignored, the elevation changes between 1977 and 1993 are significant. Horizontal accuracy and its associated errors (also thoroughly discussed in that Technical Memorandum) become less important when sounding data throughout the entire De Pere turning basin are compared. The 18-foot contour, plotted on both charts, has increased in size in the northwest and southeast direction from 1977 to 1993. Elevation losses exceeding a meter are common within the perimeter of this contour. Conversely, elevation gains of almost 70 cm are found on the upstream perimeter of the basin. Even under consideration of the most extreme error margins, this data clearly shows the dynamic nature of the sediments within the area of Transect 1A over this 16-year period of comparison.

## Master Comment 2.20

A commenter suggested that the RI/FS' analysis of transect data fails to adequately consider the standard, or expected, error in bathymetric measurements. The commenter stated that the RI/FS does not characterize and quantify error and determine if elevation changes are within expected error. Bathymetric surveys were conducted as three different accuracy levels. The RI/FS failed to adequately consider sources of error in highest accuracy surveys. Comparisons did not add together uncertainty inherent in each set of measurements.

## *Response*

Rather than estimating a combined error based on unknown indices of procedural error (as the FRG has done), the WDNR designed a field test to better define the actual combined error (equipment + procedural) of the United States Army Corps of Engineers (USACE) Class I surveys. Data collected at the SMU 56/57 demonstration site in August 1999 shows the combined vertical accuracy achieved by the USACE Kewaunee Office to be on the order of ±4 cm for their mapping work at this site on the Lower Fox River. Water depths at the site ranged from 1 to 6 meters, and accuracy was the same in deep (greater than 5 meters) water as shallow. Because these errors are random and not systematic, the combined errors associated with comparing transects from different times are not, as the FRG claims, cumulative, but rather combine as the Root-Sum-of-Squares (RSS) of the individual errors. Thus, the vertical RSS errors for the Class I transect comparisons is ±5.6 cm. Even under consideration of the highest slopes encountered in the River channel (thoroughly discussed in TM2g), the accuracy is still well within the required shallow-water range of ±15 cm.

Assuming the ±21-cm confidence interval proposed by the FRG was legitimate, and these errors were, in fact, cumulative, then the error margins associated with the pre and post-dredge hydrographic surveys of the SMU 56/57 demonstration site would translate to ±14,450 cy of sediment (723 truckloads); or ±18 percent of the total 80,000 cy removed.

## Master Comment 2.21

A commenter suggested that the RI/FS failed to consider adequately the expected error in its analysis of the EPA bathymetric data. Same-day duplicate bed elevation measurement error was 26 cm (95 percent confidence). The commenter did not think that the expected bed elevation changes are believable.

## *Response*

See response to Master Comment 2.20. Also, this point is addressed in the FIELDS Team's *White Paper No. 3 – Fox River Bathymetric Survey Analysis* in the discussion on the use of before- and after-survey bar checks.

## Master Comment 2.22

A commenter discussed the possibility of compounded error in bathymetric surveys, specific to USACE data. The author suggested that the RI/FS failed to adequately consider expected error in analysis of USACE data. ±21 cm is 95 percent confidence interval, results in no significant average bed elevation changes for several transects. New figures were constructed in Exhibit 9 to show expected changes that are within the expected error and those that are not.

## *Response*

The FIELDS Team's *White Paper No. 3 – Fox River Bathymetric Survey Analysis* uses tables and maps to demonstrate the effects of assuming that a change of ±21 cm (±1.4 feet) is the expected error in the USACE bathymetric survey data. These tables and maps demonstrate that even if this overly conservative value is used, there are still areas of considerable change in sediment elevation.

## Master Comment 2.23

A commenter suggested that due to a simple mistake, the FIELDS figures show the results of 5 years of dredging on the Lower Fox River, not sediment scour. They argue that the data we evaluated were actually surveys post-dredge rather than pre-dredge. Their figures include error, transects, and additional after-dredge and channel condition data.

## *Response*

The FIELDS Team's *White Paper No. 3 – Fox River Bathymetric Survey Analysis* report explicitly distinguished pre- from post-dredge survey results (see Table 2). In order to distinguish sediment elevation changes caused by events other than dredging, the FIELDS report performed separate analyses of non-dredge areas. The results of these comparisons are provided in both the tables and maps in the report.

## Master Comment 2.24

A commenter noted that PCBs at depth are due to dredging events, not scour or mixing.

### *Response*

The Lower Fox River sediment is part of a dynamic system that warrants close monitoring and repeated dredging over time. Both the FIELDS maps and the LTI Review (LTI, 2002) show that both erosional and depositional factors are involved in the Lower Fox River sediment system. The remaining questions relate only to the magnitude of those changes. While the WDNR and EPA agree that due to dredging activities, the bathymetric surveys performed by the USACE cannot be used quantitatively to determine the true extent of sediment movement, they are an indication of a system that may warrant more detailed analysis.

The LTI Review states that “navigational dredging, not erosion, accounts for the largest areas of apparent bed elevation declines” (LTI Review, p. 1). This conclusion is correct. However, the FIELDS Team’s maps, and those in the LTI Review, show that sediment elevation changes occur in non-dredge areas, even if one accepts that the survey data are not accurate within ±1.4 feet. These elevation changes are both negative and positive proving that natural changes in sediment distribution do occur in the system, both erosive and depositional changes.

The FIELDS Team’s maps of sediment elevation changes over time only show that a change has occurred. The causation is a separate matter. No other implication as to dredging effectiveness or USACE decisions are addressed by an analysis of the change in the sediment elevation.

The LTI Review states that the FIELDS maps show limited sediment elevation changes in areas previously dredged. Such a finding is not unexpected as many dredge areas are likely to have small vertical sediment removal and, hence, River sediment dynamics will lead to deposition in these areas. The authors of the LTI Review report similar findings. They note in Section 3.1 that, “Recently dredged areas are prone to fill in more rapidly than other river reaches, and areas filling quickly are likely to be dredged often, creating a cycle of deposition – dredging – deposition” (p. 7). Nonetheless, the maps show that large areas of dredge zones do have significant decreases in sediment elevation. On a more basic level, the bathymetric surveys performed in the same areas over time simply show changes in data values. These changes do not definitively identify an area as depositional or scour.

However, as noted above, incorporation of more complete survey dates and dredge dates into these analyses will help shed light on this subject.

The dynamic nature of River sediments may cause some areas to be scoured although they may be in predominantly depositional areas. Hence, the USACE performs dredging to remove deposition (shoals) over large areas such as the Fort Howard Turning Basin (FHTB) even though some portions of these areas may have scour.

The LTI Review, using more recent USACE survey data found that “For all year-to-year survey comparisons, the fraction of the bed showing detectable increases in elevation exceeds the fraction showing detectable declines” (LTI Review, p. 9). The authors of the LTI Review have also concluded that the sediment in the Lower Fox River is dynamic in both eroding and depositing sediment from one area to another. That USACE dredging is necessary is proof that the River sediment is dynamic and that movement of sediments occurs. Although sources of this sediment cannot be definitively determined by a bathymetric survey, likely sources of the sediment are runoff (lateral sources), upstream sources, and siltation of existing River sediment. The important point is that, since sediment is being both eroded and deposited in the Lower Fox River system, reasonable care should be taken to avoid having contaminated sediments move into areas currently below the risk level and to avoid having surface sediments with low concentrations of contamination move to expose underlying sediments with higher concentration contamination. Even if net scour is significantly lower than net deposition the preferential movement of certain sediments could greatly increase the overall surface concentration of PCBs, and greatly increase the cost of remediating contaminated sediments as they spread.

### References

Limno-Tech, Inc., (LTI), *Review of USEPA FIELDS Analysis of Bed Elevation Changes in the Lower Fox River*. January, 2002. Referred to in the document as “LTI Review.”

EPA, 2002. FIELDS Team’s *White Paper No. 3 – Fox River Bathymetric Survey Analysis*

## 2.7 Lower Fox River Dams

### Master Comment 2.25

A commenter expressed concern that the statement in the Proposed Plan that dams could fail with the result being a massive dislocation of PCB deposits from the River is highly improbable, and that historical records allow the operators to predict and then moderate flows.

### *Response*

As part of the response to comments, WDNR evaluated the dams on the Lower Fox River. These dams are all inspected on a regular basis, have to undergo re-licensing every 20 years by the Federal Energy Regulatory Commission (FERC), and there are no plans to remove any of the dams at this time. Furthermore, this inspection and licensing program should avoid any catastrophic dam failure. If a decision is made to remove a dam, the water behind the dam would need to be gradually lowered which could result in resuspension of sediment and PCBs. It is also important to note that the dams on the Lower Fox River were not constructed as flood control structures. See also *White Paper No. 4 – Dams in Wisconsin and on the Lower Fox River*.

Therefore, these evaluations consider not only dam failure, but the process for possible dam removal and benefits. If a remedy (e.g., capping) precludes dam removal, then costs and responsibility for maintenance and protection of dams in perpetuity must be considered.

## 2.8 Adequacy of Data Collected to Support the RI/BLRA/FS

### Master Comment 2.26

A commenter stated that per the Proposed Plan, an average between 125 and 220 kg of PCBs are exported annually from the Lower Fox River to Green Bay, whereas water column samples collected from July 2000 to July 2001 (high and low tides) show annual export rate is 83 to 103 kg of PCBs.

### *Response*

This statement is part of the opening summary of the WTMI Company’s comments. The paragraph containing this comment begins “The agencies’ conceptual representation of the PCB problem at the Lower Fox River/Green Bay site (“the Site”) is factually inaccurate.” This comment is listed as one of the four examples where “In key respects, the Proposed Remedial Action Plan (“PRAP”) and supporting technical documents (collectively “the PRAP documents”) overstate the PCB problem.”

The loading estimate provided in this comment is interesting, but the 2000/2001 data uses sampling and analysis techniques without including comparability with historic data as one of the data quality objectives; and the 2000/2001 annual mass estimates are based on significantly fewer data points. It cannot be concluded that loading estimates in the RI/FS and Proposed Plan are factually inaccurate.

## Master Comment 2.27

Commenters suggested that the Proposed Plan estimates 30,000 kg of PCBs in the Lower Fox River and 69,000 kg of PCBs in Green Bay are not accurate. The FRG estimates 29,000 kg of PCBs in the Lower Fox River and 18,000 kg in Green Bay. The FRG believes their estimates mean that today -30 years after PCB releases essentially stopped, PCBs are buried in significant portions of the River sediment, and are not at all being flushed to the Bay.

### *Response*

The estimates of PCB mass in the Lower Fox River and Green Bay are generated from Technical Memoranda 2e and 2f, respectively, which are included in the MDR. The difference in mass estimates in the River is small between WDNR and the FRG. WDNR and EPA disagree with the FRG that all PCB mass in the River is buried. Numerous studies have identified the riverbed as being dynamic (e.g., TM2f) and the FIELDS Team's *White Paper No. 3 – Fox River Bathymetric Survey Analysis*) and water column samples continue to show exceedances in water quality standards for PCBs indicated that a source remains.

## Master Comment 2.28

A commenter suggested that the statements on changes of PCB concentrations are based on insufficient data.

### *Response*

The RI/FS and the TTA are based upon the comprehensive data sets assembled in the Fox River Database (FRDB), while more data is always preferred, WDNR and EPA believe that the over 500,000 records within FRDB are statistically robust upon which to base the properly qualified conclusions in the TTA.

The FRG included a copy of their database, FoxView, with their comments to the Proposed Plan. A comparative analysis of the FRDB and FoxView has been completed. The goal of the analysis was to determine what data, if any, existed in the FoxView database but not in the FRDB, and the importance of that data to the RI/FS. The analysis concluded that upon incorporating the data submitted during the comment period into the FRDB, there will be a less than 1 percent difference in the final comparative record counts. This indicates that with respect to the substantive, RI/FS supporting data, there is no effective difference between the FRDB and FoxView databases. The full analysis is presented in *White Paper No. 14 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, and Proposed Remedial Action Plan.*

# 3 Risk Assessment

## 3.1 Baseline Human Health Risk Assessment

### 3.1.1 PCB Toxicity

#### Master Comment 3.1

Commenters stated that the BLRA overestimates the toxicity of PCBs to humans because of three conditions:

1) The WDNR BLRA relied on toxic values calculated from animal studies and ignored evidence from more than 20 human epidemiological studies;

2) The high-intake consumer threshold was added because WDNR estimated that many of the recreational angler exposure thresholds would be met within 30 years without implementation of an active remedy (see FS at 5-4); and

3) The risk assessment did not adequately differentiate risk from reach to reach.

#### *Response*

WDNR and EPA have concluded that the use of EPA-derived toxicity criteria is appropriate for the human health risk assessment. These values were developed according to standard methodologies and, therefore, present a relative measure of the potential for adverse effects. Both the cancer slope factor (CSF) and the reference dose (RfD) that were used in the BLRA were also used by EPA in the Hudson River Risk Assessment where PCBs were also the primary contaminant of concern (COC). In defense of these values, the EPA has prepared white papers on PCB Carcinogenicity and Non-Cancer Toxicity as part of the Hudson River Responsiveness Summary ROD and both of these white papers are attached to this Responsiveness Summary (EPA, 2002). These papers include reviews of new epidemiological and toxicological information, and this information is also summarized in the Hudson River Responsiveness Summary ROD – Master Comments 571 and 541 (EPA, 2002). Specifically, the EPA defended its use of the current RfD for Aroclor 1254 ($2 \times 10^{-5}$) based on EPA guidelines for selecting preferred toxicity values that are used in risk assessment (EPA, 1989) and because, at the time that the RfD was developed, the information was both internally and externally peer-reviewed (EPA, 1993).

Comments received on the BLRA did not question the use of the CSF, but did question the use of the RfD. On behalf of the FRG, AMEC (2002) recommended that the RfD be 10 times higher ($2 \times 10^{-4}$) based on the application of revised uncertainty factors associated with the extrapolation from effects in monkeys to effects in humans. This revision was based on an analysis of human data and a comparison of human data to monkey data. The human data came from two capacitor manufacturing plants in New York State where workers had been exposed to Aroclor 1254. The two uncertainty factors that they recommended reducing were related to the extrapolation of subchronic to chronic data, and for inter-individual sensitivity. Currently, the EPA is conducting a reassessment of the noncancer health effects of Aroclor 1254; however, this reassessment has not been completed and it is not appropriate to use a reference dose that has not been adopted by the EPA. Preliminary findings of the reassessment indicate that the use of animal-to-human uncertainty factors are appropriate, citing results of studies that support greater sensitivity in humans than monkeys.

Use of the lower, current EPA-published reference dose is also supported in the Agency for Toxic Substances and Disease Registry (ATSDR) (ATSDR, 2002) *Toxicological Profile for PCBs*. This document presents detailed information from several studies that illustrate increased weight-of-evidence of noncancer effects (such as developmental, reproductive, immunological, and neurobehavioral effects) of PCBs at very low doses, especially in children (including fetuses and nursing infants). Many of these studies are also summarized in *White Paper No. 12 – Hudson River Record of Decision PCB Carcinogenicity White Paper* and *White Paper No. 13 – Hudson River Record of Decision PCB Non-Cancer Health Effects White Paper* (EPA, 2002) and Appendix D of the Hudson River Risk Assessment.

Inclusion of the high-intake consumer receptor is appropriate as it represents an upper end of the population of exposed anglers. This does not overstate the toxicity of PCBs, as the comments suggest, it merely presents an upper-bound estimate of intake.

WDNR and EPA believe the BLRA adequately differentiates risk for each reach/zone of the exposure area. A total of six different fish ingestion scenarios were evaluated: reasonable maximum exposure (RME) recreational angler with upper-bound concentrations; RME recreational angler with average concentrations; central tendency exposure (CTE) recreational angler with average concentrations; RME high-intake fish consumer with upper-bound concentrations; RME high-intake fish consumer with average concentrations; and CTE high-intake fish consumer with average concentrations. In addition, exposure point concentrations were calculated separately for each reach of the Lower Fox River and zone of Green Bay. As previously stated, these various exposure scenarios present the range of PCB intakes, which is independent of PCB toxicity.

In addition, *White Paper No. 12 – Hudson River Record of Decision PCB Carcinogenicity White Paper* and *White Paper No. 13 – Hudson River Record* *of Decision PCB Non-Cancer Health Effects White Paper* contain relevant discussions on this topic.

### References

AMEC, 2002. FRG's Alternative Human Health Risk Assessment of the Lower Fox River and Green Bay, Wisconsin.

ATSDR, 2002. *Toxicological Profile for Polychlorinated Biphenyls (PCBs).* Agency for Toxic Substances and Disease Registry. November.

EPA, 1989. *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual (Part A)*. EPA/540/I-89/002. United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. December.

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EPA, 2002. *Responsiveness Summary: Hudson River PCBs Site Record of Decision*. United States Environmental Protection Agency, Region 2 and United States Army Corps of Engineers, Kansas City District. January.

## Master Comment 3.2

Commenters contended that the Proposed Plan exaggerates the potential for noncancer hazards in cases where hazard indices exceed 1.0.

## *Response*

Inclusion of the high-intake consumer receptor is appropriate as it represents an upper end of the population of exposed anglers.  This does not overstate the toxicity of PCBs, as the comments suggest, it merely presents an upper-bound estimate of intake.

In addition, *White Paper No. 12 – Hudson River Record of Decision PCB Carcinogenicity White Paper* and *White Paper No. 13 – Hudson River Record of Decision PCB Non-Cancer Health Effects White Paper* contain relevant discussions on this topic.

### 3.1.2 Fish Consumption Rates (rate and species mix)

#### Master Comment 3.3

Commenters contended that WDNR human health BLRA exposure assumptions were unrealistic. These commenters specifically disagreed with the following:

1) The use of Michigan survey data (West et al., 1989, 1993) on fish consumption rates when Wisconsin data (WFOR survey) is available because they believe that fish consumption rates are exaggerated.

2) The averaging of sample results in OU 1, which included a high percentage of carp samples, even though the evidence indicates little if any carp is actually consumed from OU 1.

3) The assumption that people actually eat significant amounts of carp.

4) The omission of carp from background calculations.

5) Fish consumption goals and projections regarding the number of subsistence anglers are unrealistic. (WDNR projected that up to 13,600 individuals ignore the advisories and consume fish at "high intake" rates. Commenters suggest that a survey of 7,026 licensed anglers in Wisconsin indicates that the 13,600 figure is overstated by at least a factor of 10).

6) A differential evaluation of potential risks to native American anglers who may consume fish from the assessment area because currently available data are inadequate to permit this analysis.

7) The analysis of low-income anglers as a sensitive subpopulation because there is no basis for this analysis.

8) The omission of age- and region-specific data on human mobility which resulted in the overestimation of exposure and risk.

One commenter suggested that the FRG Baseline Human Health Risk Assessment (AMEC, 2002) contains more realistic exposure conditions that result in substantially lower estimates of risks and hazards.

#### *Response*

WDNR and EPA have determined that the exposure and intake assumptions used in the BLRA are appropriately conservative, relevant to the Site, and are consistent with standard and customary EPA approaches. Each of the individual comments are responded to in sequence below.

A comparison of the risk estimates based on the Wisconsin survey data (AMEC's Human Health Risk Assessment) and similar information from the studies used in the BLRA indicates that consumption rates and risk estimates are not significantly different. The table below summarizes the risk estimates predicted by AMEC (2002) and those derived from the focused risk assessment when comparable data are used (e.g., perch data from 1990s only; De Pere to Green Bay Reach; reasonable maximum exposure [RME] scenario). Note that both evaluations used the same toxicity criteria for PCBs and the same carcinogenic averaging time; however, the noncancer averaging time used by AMEC is 15 years, while the BLRA noncancer averaging time for the RME scenario is 50 years.

| Receptor | WDNR | AMEC | WDNR | AMEC | WDNR | AMEC | WDNR | AMEC |
|---|---|---|---|---|---|---|---|---|
| | Basis of Fish Ingestion Rates | | Annualized Ingestion Rate (g/day) | | Mean Cancer Risk | | Mean Noncancer Hazard (HI) | |
| Recreational Angler | avg. of West et al., 1989 and 1993 studies | WFOR Study by TER, 1999 | 59 (Table 5-80) | 61 (Table 4-3) | $5.7 \times 10^{-4}$ (Table 5-82) | $1.1 \times 10^{-4}$ (Table 4-1) | 21 (Table 5-84) | 9 (Table 4-1) |
| | Fiore et al., 1989 study | | 37 (Table 5-80) | | $3.6 \times 10^{-4}$ (Table 5-82) | | 13 (Table 5-84) | |
| High-intake Fish Consumer | Hutchison and Kraft, 1994 study | Based on an evaluation of 6 studies: Hutchison and Kraft, 1994; Hutchison, 1994; Hutchison, 1999; WDHSS, 1998; WFORS (TER, 1999); Steenport et al., 2000 | 81 (Table 5-81) | 90 (Table 3-27) | $7.9 \times 10^{-4}$ (Table 5-86) | $3.9 \times 10^{-4}$ (Table 4-2) | 30 (Table 5-88) | 36 (Table 4-2) |

**Table Notes:**
HI – Hazard Index
Assumptions of fish species consumed:
**WDNR –** These data presented reflect that it was assumed that only perch (white and yellow) were consumed by both recreational anglers and high-intake fish consumers.
**AMEC –** Recreational angler species preferences were based on the WFOR Study and included 95.5 percent yellow perch, 1.5 percent walleye, 1 percent white perch, and 2 percent other. High-intake fish consumer species preferences were based on Hutchinson (1998) and included 48.5 percent white perch, 16.7 percent white bass, 24.2 percent catfish, 7.6 percent walleye, and 3 percent sheepshead.

Furthermore, the studies that were used in the BLRA are appropriate and relevant for several reasons. The studies include West et al. (1989, 1993), Fiore et al. (1989), Hutchinson and Kraft (1994), Peterson et al. (1994), and Hutchinson (1999). Information from each of these studies was considered and incorporated in the derivation of risk estimates, and it was determined that upper-bound risk estimates were similar. Tables 5-82 through 5-89 provide these results for the focused evaluation, and for any given receptor-River reach-fish species subgroup evaluated; the results based on each exposure study are within a close range (within the same order of magnitude). As an example, the cancer risks for the RME recreational angler in the De Pere to Green Bay Reach using all fish species data from the 1990s (refer to Table 5-82) range from $4.6 \times 10^{-4}$ to $9.7 \times 10^{-4}$. It is also important to note that the focused evaluation considered different species of sport fish individually, as well as combined species. This approach was deemed necessary to evaluate and be fully protective of recreational sport anglers that actively fish for certain species (e.g., walleye).

The exposure estimates selected for use in the BLRA were carefully selected based on literature as well as communication with various Agency personnel. The use of the two West et al. (1989, 1993) studies for exposure estimates is further supported by the fact that these are regionally relevant data and these studies were specifically discussed in detail in the EPA *Human Health Exposure Factors Handbook* (EPA, 1997). These data were also used to derive fish consumption rates for the Great Lakes Water Quality Criteria. Furthermore, use of the WFOR study as the basis of fish consumption rates may not be appropriate. Ingestion rates that are derived from a study conducted in an area where fish consumption advisories are in place are not representative of baseline conditions, which the goal of the BLRA.

People do eat carp and this is easily demonstrated by the number of web sites dedicated to finding and preparing carp for human consumption. Examples of these web sites include: www.carpanglersgroup.org, www.carp.net, www.carpuniverse.com, and www.carpdreamfishing.com. In addition, even if the subpopulation of carp consumers is small in comparison to subpopulations that consume other types of sport fish, the BLRA should be appropriately conservative to protect all populations of fish consumers.

As noted in the response to Master Comment 3.4, only a very limited amount of data was available for skin-on fillet samples from Lake Winnebago (the background location) in the 1990s. While it is true that no carp samples were available from this specific data set, the background information is merely presented for comparison purposes. The average PCB concentration for Lake Winnebago fish can also be compared to the average concentrations presented for white bass and walleye from the Site (these two species comprised six of the seven background samples), and this comparison also shows that concentrations in the reaches and zones are elevated above background.

The number of "high intake consumers" estimated in the risk assessment is said to be overstated. This number does not affect the resulting calculated risks for a high-intake consumer. Although there may not be adequate data to evaluate specific subpopulations (e.g., low-income, native American, etc.), this was not an objective of the risk assessment. The objective was to estimate risks to a high-intake consumer, regardless of the number of people that fall under this category or what other subpopulation they may be grouped into.

Information on human mobility was considered in the selection of the appropriate exposure duration (ED) for the angler. Appendix B1 of the BLRA presented detailed calculations of the time the potentially exposed population of anglers are expected to catch fish in the Lower Fox River and Green Bay.

The fundamental assumption used in this analysis is that the number of years the angler fishes is equal to the number of years the angler lives in the Lower Fox River and Green Bay region. The calculation presented in the BLRA recognizes that different anglers will spend different times in the area and, therefore, generate a probability distribution for ED. This probability distribution depends on the age of a receptor when that individual moves into the region, and the percent of times a move is within the region (as opposed to moving out of the region). Depending on the assumptions made for these two parameters, the mean of the probability distribution of ED ranges between 18 years and 33 years. The 95 percent value ranges between 25 and 75 years. ED values of 30 years for the CTE scenario and 50 years for the RME scenario were established based on professional judgment prior to developing the probabilistic analysis described in Appendix B1. These CTE and RME values are, however, consistent with the probability distributions, so these values are retained as the CTE and RME values for this analysis.

One of the main differences in the exposure estimates between the AMEC and human health portion of the BLRA is that the AMEC Human Health Risk Assessment assumed that fish tissue concentrations were declining and the WDNR BLRA assumed that fish tissue concentrations were static. This difference results from the fact that different data were used in the exposure analysis. WDNR performed an extensive time trends analysis (RI Appendix B), which indicated that fish tissue concentrations were not consistently declining for species that are routinely consumed by humans. In the absence of statistical confirmation that tissue concentrations were declining, exposure concentrations were assumed to be static. An assumption of declining fish concentrations would have to be well supported by the data in order to be certain that human health was being adequately protected. Additionally, even if fish concentrations were found to be declining over time, people have potentially been exposed to historically higher concentrations in fish for the past 30 years. Given the uncertainty in whether fish tissue concentrations were declining and the uncertainty associated with how long people may have been exposed to historically high PCB concentrations, WDNR used a static point estimate for fish tissue exposure concentrations.

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Fiore, B. J., H. A. Anderson, L. P. Hanrahan, L. J. Olson, and W. C. Sonzogni, 1989. Sport fish consumption and body burden levels of chlorinated hydrocarbons: A study of Wisconsin anglers. *Archives of Environmental Health*. 44(2):82–8.

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## Master Comment 3.4

Commenters stated that that cancer risk from eating fish caught at the Site is 20 times greater than from eating fish at Lake Winnebago (background) and that this is an overstatement because Lake Winnebago calculations excludes carp and the Site calculation includes carp.

## Response

WDNR and EPA contend that exposure point concentrations for PCBs in fish are appropriately conservative for the BLRA. Comments indicate that carp tissue samples were resulting in an unrealistic representation of amount of PCBs in fish that are consumed, especially when comparing with background. There are populations of anglers that do consume carp (refer to websites listed in the response to Master Comment 3.3), and these populations must be considered in the risk assessment. The samples available for carp were included in the statistical calculations with the same weighting as all other fish species. In the majority of reaches and zones, carp comprise only a small percentage of species that were sampled (refer to Tables 5-76 and 5-78 of the BLRA); therefore, concentrations in carp do not necessarily result in unrealistically high PCB concentrations overall.

Regarding the lack of carp data included in the background calculations, only a very limited amount of data was available for skin-on fillet samples from Lake Winnebago in the 1990s (seven samples to be exact). While it is true that no carp samples were available from this specific data set, the background information is merely presented for comparison purposes. The average PCB concentration for Lake Winnebago fish can also be compared to the average concentrations presented for white bass and walleye from the Site (these two species comprised six of the seven background samples), and this comparison also shows that concentrations in the reaches and zones are elevated above background.

It would be extremely difficult to determine the percentage of each fish species that people are likely to consume on a reach- and zone-specific basis, and then area-weight the PCB concentrations for those species to arrive at a representative PCB concentration. While carp consumption may be overestimated, it is our opinion that the calculations are appropriately conservative to protect all populations of fish consumers.

Note also, the WDNR evaluation assumes that concentrations of PCBs in fish are constant over time. An assumption of declining fish concentrations would have to be well supported by the data in order to be certain that human health was being adequately protected. An extensive time trends analysis was performed that indicated that fish tissue concentrations were not consistently declining for species that are routinely consumed by humans. In the absence of statistical confirmation that tissue concentrations were declining, exposure concentrations were assumed to be static. Furthermore, even if it were possible to accurately predict future PCB concentrations in fish, there is substantial uncertainty in such projections. First, historical trends may not be accurate predictors of future trends. The fact that some time trends fit a double exponential function where the concentrations declined at a faster rate in the early 1980s than in the late 1990s suggests that future declines could be at an even slower rate. Second, the historical data are typically available for a period of 15 to 25 years, whereas the exposure periods of interest are 30 to 50 years. Thus, using historical data to predict future concentrations requires the additional assumption that the historical data will accurately reflect future concentrations over future time periods that are two to three times longer than the historical time period. The use of historical data from a 25-year period to predict concentrations over the next 5 years will give far more reliable results than the use of this same historical data to predict concentrations over the next 50 years. Finally, use of static concentrations provides an extra measure of conservatism should future disturbance of sediments (via flooding, ice scour, etc.) occur. Given the uncertainty in whether fish tissue concentrations were declining and the uncertainty associated with how long people may have been exposed to historically high PCB concentrations, WDNR used a static point estimate for fish tissue exposure concentrations.

## Master Comment 3.5

A commenter questioned if there really was any risk from eating the fish, and stated individuals must decide for themselves what is an appropriate risk level.

### *Response*

WDNR and EPA followed appropriate guidance in assessing risk, and stand by the risks identified in the BLRA for humans. See also response to Master Comment 3.3.

In addition, *White Paper No. 12 – Hudson River Record of Decision PCB Carcinogenicity White Paper* and *White Paper No. 13 – Hudson River Record of Decision PCB Non-Cancer Health Effects White Paper* contain relevant discussions on this topic.

## Master Comment 3.6

Commenters expressed their opinion that no remedy would be sufficient to enable the removal of advisories for high-intake fish consumers.

### *Response*

WDNR and EPA believe this remedy will meet the RAO of removing consumption advisories. Active remediation will accelerate the reduction in fish tissue concentrations of PCBs to background levels. The Agencies will continue to plan to use existing protocol to determine the need for fish consumption advisories.

## Master Comment 3.7

Commenters expressed concern that the key to risk reduction at this Site is to reduce the PCB concentrations in fish that are consumed by human or ecological receptors. Other exposure pathways are not of significant concern.

### *Response*

The BLRA did not conclude that eating fish was the sole route for PCB and mercury exposure and risk. Other pathways (e.g., waterfowl consumption) were also found to be of concern. The risk assessment did, however, conclude that the greatest exposure and risk are directly tied to fish consumption. WDNR and EPA believe that reducing risks from eating fish will result in reduced risks from all pathways.

## 3.1.3 Probabilistic Analysis

### Master Comment 3.8

Commenters stated that a probabilistic risk assessment is far more appropriate than a point estimate analysis for risk management decisions at large sites.

### *Response*

WDNR and EPA have concluded that the range of evaluations presented in the BLRA is appropriate for purposes of risk management decisions. The BLRA includes a wide range of calculated results for the two most sensitive receptors, the recreational angler and the high-intake fish consumer. Two RME scenarios have been assessed, one using upper-bound concentrations and the second using average concentrations, and a CTE scenario was assessed. Furthermore, the focused evaluation of PCBs from fish ingestion explored a wide range of exposure scenarios incorporating various intake assumptions and PCB concentrations. As part of the focused evaluation, a probabilistic risk assessment of exposure assumptions for the recreational angler and high-intake fish consumer was conducted and was summarized in the BLRA Section 5.9.6 and detailed in Appendix B1. The probabilistic evaluation analyzed the influence of variability by developing probability distributions for exposure parameters listed below:

- Fish concentration (three distributions were used):
  - Concentrations developed by Exponent (2000),
  - Concentrations from all fish species in Little Lake Butte des Morts Reach, and
  - Concentrations from all fish species in De Pere to Green Bay Reach;

- Fish ingestion rate and exposure frequency (for both recreational anglers and high-intake fish consumers based on the studies below):
  - Recreational angler:
    - West et al. (1989),
    - West et al. (1993),
    - Average of West et al. (1989 and 1993), and
    - Fiore et al., 1989;

- High-intake fish consumer:
  - Low-income minority (West et al., 1993),
  - Native American (Peterson et al., 1994 and Fiore et al., 1989),
  - Hmong (Hutchinson and Kraft, 1994), and
  - Hmong/Laotian (Hutchison, 1999);

- Reduction factor;

- Exposure duration; and

- Body weight.

A comparison of the results of the point estimate evaluations and probabilistic evaluations indicates that for similar sets of intake and data assumptions, the results of the point estimate evaluations are comparable to the 95th percentile results of the probabilistic evaluation. The table below presents the range of cancer risks (using the various studies for ingestion rates) for a recreational angler and high-intake fish consumer using concentrations for all fish species from the De Pere to Green Bay Reach.

| Receptor | Focused Point Estimate Risk Range | 95th Percentile Probabilistic Risk Range |
|---|---|---|
| Recreational Angler | $4.6 \times 10^{-4}$ to $9.7 \times 10^{-4}$ (Table 5-82) | $4.2 \times 10^{-4}$ to $8.5 \times 10^{-4}$ (Table 5-97) |
| High-intake Fish Consumer | $4.0 \times 10^{-4}$ to $1.4 \times 10^{-3}$ (Table 5-86) | $2.4 \times 10^{-4}$ to $1.4 \times 10^{-3}$ (Table 5-98) |

The results above show that the RME point estimates of cancer risk are comparable to the 95th percentiles of the probability distributions of cancer risk. These results are consistent with the EPA (1999) interpretation of the RME scenario as a plausible high-end representation for the exposed population and protective of human health. As a result, WDNR and EPA conclude that the range of evaluations presented in this assessment sufficiently illustrates potential risks for average to high-end receptors. Importantly, EPA guidance specifies that point estimates of risk be used as the principal basis for decisions regarding the need for remedial action at a site (p. 5-120).

## References

Exponent, 2000. *Baseline Human Health Risk Assessment of PCBs in the Lower Fox River System*. Prepared for the Fox River Group and Wisconsin Department of Natural Resources. Landover, Maryland.

Fiore, B. J., H. A. Anderson, L. P. Hanrahan, L. J. Olson, and W. C. Sonzogni, 1989. Sport fish consumption and body burden levels of chlorinated hydrocarbons: A study of Wisconsin anglers. *Archives of Environmental Health*. 44(2):82–8.

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# 3.2 Baseline Ecological Risk Assessment

## 3.2.1 Ecological Toxicity of PCBs

### Master Comment 3.9

Commenters stated that the amount of PCBs in the eggs of a female fish is most likely determined by the relative lipid content (egg versus whole body), which varies considerably among species. It will be very different for salmon and lake trout (which tend to have lower relative lipid content in their eggs compared to other species; see e.g., Niimi and Oliver, 1983). This method introduces uncertainty into the toxicity reference value (TRV) derivation.

### *Response*

In the BLRA, the PCB TRVs selected for fish were not lipid content-specific because the assessment endpoints of benthic and pelagic fish included fish of varying lipid contents. Therefore, the influence of lipid content on PCB bioaccumulation was not factored into the estimation of toxicity. The toxicity estimation was based on the total body content of PCBs. Lipid content in fish was, however, considered during the calculation of SQTs using bioaccumulation modeling.

**Referencs**

Niimi, J. and B. G. Oliver, 1983. Biological half-lives of polychlorinated biphenyl (PCB) congeners in whole fish and muscle of rainbow trout. *Canadian Journal of Aquatic Sciences*. 40:1388–1394.

### Master Comment 3.10

Commenters contend that the discussion of sediment appears to totally ignore the organic carbon content.

### *Response*

These data were not ignored and sediment organic carbon concentrations were factored into the sediment quality thresholds that were derived. Sediment PCB concentrations were not, however, normalized to organic carbon concentrations because the sediment PCB threshold effect level for invertebrates was not dependent on organic carbon content.

## 3.2.2 PCB Congeners

### Master Comment 3.11

WDNR received several comments regarding PCB analytical data used in the risk evaluation. While WDNR used both total PCB data and PCB congener data in the BLRA, a commenter contended that only PCB congener data should have been evaluated and that because total PCB data were evaluated, the BLRA significantly overestimates current and future ecological risks presented by the Lower Fox River and Green Bay.

Other commenters did not understand why PCB congener data were presented in terms of individual congener concentrations instead of toxic equivalency (TEQ) concentrations. Regarding the nomenclature used for dioxin and furan congeners, a commenter believed that the terminology should be more consistent.

### *Response*

Both total PCB toxicity and congener-specific toxicity were evaluated in the BLRA. WDNR and EPA believe that both evaluations were necessary and consistent with risk assessment guidance, and with the recommendations of the NRC.

The PCB TRVs were derived from an exhaustive search of the scientific literature available at the time. Many of the studies found in the search were determined to be lacking one or more pieces of information that precluded their use in the BLRA. The remaining studies (i.e., those that were judged, based on sound science and professional experience to be credible) were used to derive the TRVs in consultation with the BTAG assembled for the ecological risk assessment in the BLRA.

In a literal sense, only 2,3,7,8-TCDD and 2,3,7,8-TCDF were carried forward as chemicals of potential concern (COPCs) as noted in the letter from Bruce Baker (attached as Appendix A to the BLRA). However, to be comprehensive, in the toxicological evaluation it was necessary to not only evaluate 2,3,7,8-TCDD and 2,3,7,8-TCDF, but all dioxin and furan structurally related compounds that are known to cause Ah-R-mediated toxicity to fish and wildlife. Minor revisions were made to the BLRA text to clarify this point. The dioxin and furan congener toxicity risk analysis was limited to those congeners that were analyzed in tissues and those congeners for which there were toxic equivalency factors (TEFs). The presentation of individual dioxin, furan, and PCB congener concentrations in the WDNR BLRA ecological exposure assessment instead of the total TEQ concentration was intended to transparently detail which congeners most significantly were responsible for the calculated exposure. TEQ exposure concentrations are presented in the risk characterization section of the BLRA.

In the fall of 2001, the World Health Organization (WHO) held a conference in Berlin, Germany to discuss risk assessment of non-dioxin-like PCBs (WHO, 2001). The toxicity of PCB congeners that bind to the Ah-receptor and are known to cause dioxin-like effects and this toxicity is evaluated though the application of TEFs. It is unclear, however, if this quantification of the toxicity of PCB congeners adequately characterizes the potential for risk from all PCB congeners. The TEF system of toxicity quantification does not directly apply to non-dioxin-like congeners because non-dioxin-like congeners do not have a common mechanism of action (WHO, 2001). It is important to better understand the potential for toxicity caused by non-dioxin-like congeners because the concentrations of these congeners in environmental media are much higher than the concentrations of dioxin-like congeners and, therefore, toxicity may be largely underestimated.

The Berlin conference in 2001 (WHO, 2001) identified approaches for the evaluation of non-dioxin-like PCB congeners. Resulting from this conference, the following non-dioxin-like PCB congener endpoints were identified: intracellular $Ca^{2+}$ mobilization, Protein Kinase C (PKC) translocation, binding to the ryanodine receptor, induction of CYP2B/3A, estrogenicity, tumor promotion, immutoxic effects, neurotoxic effects (chemical, structural, functional), and other endocrine-related effects (insulin, thyroid hormone). It was noted that these endpoints may also be affected by dioxin-like PCB congeners. It is challenging to determine which effects are the result of dioxin-like congeners only, given exposure to a chemical mixture. In addition to recommending the toxicity evaluation of these endpoints, this conference panel recommended that a survey be conducted of the available exposure data with respect to the ratio of non-dioxin-like PCBs and dioxin-like PCBs, and non-dioxin-like PCBs and TEQs, respectively (WHO, 2001). It is clear from this conference that the WHO is concerned with the toxicity of all PCB congeners (209 total) and not just the 20 PCB congeners that are planar and exhibit dioxin-like toxicity. In the absence of clearly defined investigation methods for non-coplanar PCB toxicity, only analysis of total PCB toxicity can be used to characterize the risk from all PCB congeners.

Non-coplanar PCB congener toxicity is known to be potentially important and has been demonstrated at least in mammals (EPA, 2001; Giesy et al., 2000). There is not enough information in the scientific literature to evaluate the toxicity of non-coplanar congeners. The only way WDNR could be inclusive in the risk evaluation for the potential of non-coplanar toxicity was through the evaluation of total PCB toxicity. The evaluation of total PCBs is likely a conservative evaluation of the potential for non-coplanar PCB toxicity and in the absence of definitive information, the EPA requires that risk assessments err on the side of being adequately conservative. Non-coplanar PCB toxicity may be very species specific and may especially vary across phyla (e.g., fish, birds, and mammals). Even if it were possible to rigorously evaluate non-coplanar PCB toxicity would only have provided another line of evidence and even without an additional line of evidence toxicity was indicated. Therefore, knowledge of potential non-coplanar toxicity would only add to this argument that there is the potential for toxicity. In the review of both WDNR and FRG ecological risk assessments the Association for Environmental Health and Sciences (AEHS) made the following comment: “While much of the toxicity associated with PCBs may be related to Ah-R interactions, this association does not apply to several toxic effects (e.g., estrogenicity neurotoxicity). Thus, the use of both approaches is appropriate.” (AEHS, 2000, p. 33).

Recently, the U.S. Navy prepared an ecological risk assessment issue paper comparing the advantages and disadvantages of risk analysis with PCB congeners as compared to total PCBs. A conclusion was that although PCB congener analysis does have advantages over Aroclor analysis including increased chemical specificity and detection limits, a primary disadvantage of the risk analysis of PCB congeners is that most of the PCB effects data in the literature is based on total PCB concentrations (Bernhard and Petron, 2001). This conclusion is supported by the scientific literature that was reviewed and included in the WDNR BLRA.

### References

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EPA, 2001. *Dose Response Assessment from Recently Published Research of the Toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Related Compounds to Aquatic Wildlife – Laboratory Studies*. United States Environmental Protection Agency.

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## 3.2.3 Screening Level vs. Baseline Risk Assessment

### Master Comment 3.12

Commenters stated that ecological risks have been significantly overstated in the WDNR's BLRA largely because they contend that the WDNR ecological portion of the BLRA primarily focused on screening level risk rather than baseline risk. This same comment was also received from an earlier review of the draft BLRA conducted in 2000 by AEHS, an independent review panel (AEHS, 2000). As an alternative, some commenters challenged that the ecological risk assessment conducted by the FRG (BBL, 2002) is superior because it evaluates risks beyond the screening level analysis, is a more accurate evaluation of ecological risks, and was conducted in accordance with applicable guidance documents. The ecological risk assessment produced by the FRG supported a finding of no or low ecological risk from PCB exposure.

### *Response*

WDNR and EPA disagree that the BLRA ignores EPA guidance. On the contrary, the risk assessments are consistent with guidance. The ecological risk assessment in the BLRA, specifically, was prepared with the assistance of the site-specific BTAG and EPA's national expert on ecological risk assessment. One of the charges of the BTAG and the national expert was to ensure that the BLRA followed EPA guidance. Whenever inconsistencies were noted, they were corrected so that the final document was in fact in accordance with EPA guidance.

A screening level ecological risk assessment provides a comparison of abiotic media concentrations to ecotoxicological benchmarks. Screening level ecological risk assessments do not include extensive site-specific information. The BLRA produced by WDNR included extensive site-specific information with regard to the nature and extent of the contamination, receptor-specific exposure factors, and species-specific information that was preferentially used in developing TRVs. Both NOAELs and LOAELs were used to put bounds on the risk estimates. Exposure concentrations were derived for not only abiotic media, but also for wildlife receptors and two exposure thresholds were calculated and used to bound the risk analysis; the mean and the 95 percent UCL of the mean. Wildlife receptor exposure estimates were determined from site-specific data as available and from exposure modeling using well-researched exposure assumptions. Not only did these exposure data standardize risk comparisons between regions, but modeled exposure data could be compared to actual Site data in some regions to determine the relative agreement between these two exposure estimation techniques. The selection of adverse effect levels was determined from the review of numerous articles from primary scientific literature. Additionally, the discussion surrounding the selection of these TRVs was standardized to make the selection process transparent. Regarding the risk characterization and summary process, the WDNR BLRA described risk interpretation, extensively summarized risks by area and by media, and included a summary of field study results.

A separate response to AEHS comments that were submitted in June 2000 has been prepared. As discussed in this response, the concerns of the AEHS panel were largely addressed in the Draft BLRA that was released in February 2000.

**References**

AEHS, 2000. *Peer Review Panel Report for the Fox River Human and Ecological Risk Assessments*. Association for the Environmental Health and Sciences, Amherst, Massachusetts.

BBL, 2002. Baseline Ecological Risk Assessment of the Lower Fox River and Green Bay, Wisconsin. Blasland, Bouck and Lee. January.

## 3.2.4 Habitat and Population Studies

### Master Comment 3.13

Commenters contended that, currently, PCBs are not a cause of many use impairments or suspected impairments of Lower Fox River and Green Bay system. The PCBs in the system do not cause: (1) degraded fish or wildlife populations, (2) tainting of fish or wildlife flavors, (3) fish tumors or other deformities, (4) eutrophication or undesirable algae, (5) drinking water consumption or taste or odor problems, (6) beach closings, (7) degradation of aesthetics, and (8) loss of fish and wildlife habitat. In fact, the causes of these impairments include nutrient loadings, suspended solids, stormwater runoff, turbidity, and land development.

### *Response*

WDNR and EPA did not claim that PCBs are the source of all the impairments identified for the Lower Fox River and Green Bay in the

Proposed Plan. However, WDNR and EPA do believe that PCBs are the major contaminant contributing to consumption advisories – and unacceptable health risk to those who do not follow the advisories – PCBs are suspected to be an impairment for degraded fish and wildlife and fish health-related alterations, degradation of benthos as well as populations of phytoplankton and zooplankton, restrictions on dredging activities, and additional costs to industry. WDNR and EPA also believe that significant reduction in PCBs in the River will go a long way to addressing other River impairments to use of the Fox River and Green Bay and once the PCB problem is addressed, it will make even greater sense to address remaining issues.

## Master Comment 3.14

Commenters stated that the BLRA does not place sufficient reliance on the conclusions of USFWS reports.

## *Response*

The WDNR participated in extensive discussions with the Biological Technical Assistance Group (BTAG), which included the USFWS and other trustees. The BTAG discussed published USFWS determinations and underlying studies and data, at length. Furthermore, the USFWS and other trustees commented extensively on proposals, language, and drafts that led to the RI/FS and Proposed Plan. In some cases, WDNR, in consultation with the EPA, adopted USFWS and other trustee comments. In fact, the WDNR requested and used USFWS and other trustee analyses and language in parts of the RI/FS. Significant USFWS and other trustee comments that were adopted by WDNR and EPA include: (1) incorporation of Green Bay into the RI/FS; (2) inclusion of ecological risk endpoints other than population endpoints; (3) incorporation of assessment data, analyses, and determinations into the RI/FS; and (4) incorporation of PCB fate and transport model documentation into the RI/FS.

On July 11, 1997, WDNR and EPA joined the other trustees to form the Intergovernmental Partnership (IGP), through a Memorandum of Agreement (MOA). The MOA was designed, in part, to coordinate response and restoration activities undertaken by the IGP. The response Agencies have clearly devoted considerable effort to coordinate with the USFWS and other trustees. However, the responsibility to weigh the merits of trustee determinations, comments, and positions for use in response actions belongs to WDNR and EPA. WDNR and EPA believe that they have considered trustee and other comments and that they have adopted those comments that merit inclusion.

The USWFS NRDA reports were designed to answer questions of injury, but not risk, they focused on individual species, and for some species the results are largely inconclusive. Importantly, the Agencies did consider and discuss all of the USFWS NRDA evaluations and used these studies in the BLRA to the extent that they were applicable to the evaluation of risk to assessment endpoints.

The BLRA discussed at length not only the USFWS NRDA studies, but also other field studies that had already been conducted on the Lower Fox River and Green Bay. In fact, these studies were presented as part of an integrated tool for risk managers to make informed decisions regarding ecological risk in the River and/or Bay. Specifically, Section 6.5.4 of the risk characterization section of the BLRA presents detailed summaries of the field studies involving water column invertebrates, benthic invertebrates, benthic fish, piscivorous fish, insectivorous birds, piscivorous birds, omnivorous birds, and piscivorous mammals. Studies on tree swallows by Custer et al. (1998) were used as a line of evidence in evaluating risks to the insectivorous bird assessment endpoint in Little Lake Butte des Morts and in Green Bay zones 1 and 2

### Referencs

Custer, C. M., T. W. Custer, P. D. Allen, K. L. Stromborg, and M. J. Melancon, 1998. Reproduction and environmental contamination in tree swallows nesting in the Fox River drainage and Green Bay, Wisconsin, USA. *Environmental Toxicology and Chemistry*. 17(9):1786–1798.

## Master Comment 3.15

Commenters stated that benthic fish, pelagic fish, passerine birds, terns, and double-crested cormorants are not subject to population-level baseline risks associated with PCB exposure in the Lower Fox River and Green Bay.

## *Response*

There appears to be some confusion between assessment endpoints and representative receptor species. This comment tends to focus on individual species such as terns and cormorants, when in fact, the BLRA used these species to represent all piscivorous birds, which could use the Lower Fox River system. It is important to recognize the distinction between the assessment endpoint and the measurement endpoint to avoid confusion between presence or absence of one species, with risk to the entire assessment endpoint. For example, terns and cormorants were species evaluated to represent the piscivorous bird assessment endpoint. To that end, adverse impacts to these species are meant to be representative of all piscivorous birds. Other species of piscivorous birds may be present (e.g., gulls, heron, egrets, etc.) that were not specifically evaluated, but must be protected. Therefore, it is imperative to be conservative, yet scientifically sound, when translating impacts on a given species to the assessment endpoint. That is, lack of impact on one receptor species does not mean the assessment endpoint is not at risk.

Additionally, the comment refers to population level baseline risks, when there is no discussion of this in the assessment endpoint that was evaluated (e.g., piscivorous bird reproduction and survival). The assessment endpoint focused on protecting reproductive rates and survival of birds, not necessarily all bird populations.

At the start of the risk assessment process for the Lower Fox River and Green Bay, there was discussion of initiating studies to address issues of risk directly on field populations of wildlife that use the Site. However, these types of studies generally require many years of data to be able to discern adverse effects due to contamination, and to differentiate the contaminant effects from adverse effects due to something else (e.g., food sources, predation, competition, immigration, emigration, weather, etc.). As such, a collective management decision was made to utilize the already existing data to evaluate and characterize risk.

Population measurement endpoints are appropriate when the data are collected to answer risk questions. Population data were included in the BLRA but were ultimately not used as lines of evidence for risk conclusions because causal evidence for increases or decreases in populations were not investigated. While these studies provide good information, they do not provide a definitive answer relative to the risk posed by the COPCs at the Lower Fox River Site.

While contaminant conditions may exist that would jeopardize the health of an assessment endpoint, the absence or presence of a given receptor species does not, by itself, indicate risk or no risk due to contamination. Likewise, the apparent increase of some populations (e.g., walleye and cormorants) is not inherently inconsistent with a conclusion of contaminant risk being present to piscivorous fish or piscivorous birds. The River and the Bay have been recovering from years of free dumping of waste products during the early to middle part of the 1900s. Years ago, the River had such a high biological oxygen demand that virtually no fish species were present. The rebounding of fish and wildlife populations because of better habitat (e.g., higher oxygen levels) and fewer contaminants does not indicate that there is no potential for adverse responses to Site contaminants. An increase in wildlife using the area implicitly increases the potential for exposure to contaminants to occur.

## Master Comment 3.16

Commenters stated that that site-specific habitat and exposure data for risk quantification were ignored and that this goes against EPA risk assessment guidance which states “risks to organisms in field situations are best estimated from studies at the site of interest” (EPA, 1998). Comments indicated that many site-specific data contained within the FRDB (including data collected by the FRG, the USFWS, EPA, WDNR, universities, and other organizations and institutions) were not used as part of the risk investigation. One comment specifically addressed the fact that tern habitat is limited to the mouth of the River and Renard Island, and that the USFWS NRDA study showed no current risk to Caspian terns.

### Response

The BLRA did in fact use site-specific habitat data. For example, insectivorous birds were not evaluated in two reaches of the River and three zones of the Bay due to habitat constraints. Additionally, alewife and smelt were evaluated in zones 1 and 2 but not in the River due to the habitats being appropriate in one location and not in the other. Lake trout were evaluated in the Bay and not in the River because that is where they are found. It would be inappropriate to consider lake trout in the River due to its habitat requirements. Further, Section 6.5.4 of the BLRA extensively discusses the field studies performed on the Fox River for water column and benthic invertebrates; benthic and piscivorous fish; insectivorous, piscivorous and omnivorous birds; and piscivorous mammals.

The question of whether the Lower Fox River contains, or the extent to which it contains, high quality habitat for the measurement endpoint receptor species (e.g., mink and terns), while important in making management decisions, is not strictly a contaminant risk issue. In addition, the argument that there is low habitat quality and thereby low risk has logic flaws because organisms that do use the area are still potentially at risk. If viable habitat exists or may exist, the organisms that use the habitat will be exposed to the contaminants. Given the goals of the NRDA, there is no way to forecast what sort of land use may occur in the future that may provide better habitat, potentially increasing the number of organisms exposed.

The data that were extracted from the FRDB and used for risk analysis were limited by receptor, by date of collection, and by data quality constraints. A full description of the data (type and quality) contained in the FRDB and used in the risk analysis is contained in Section 4 of the BLRA. In addition to the numerous Site data that were analyzed, the BLRA used information collected from recent scientific literature in the risk analysis.

There are several additional articles related to PCB toxicity in bald eagles, mink, and other mammals that have not been included in the risk evaluation either because the conclusions of these articles were considered to not influence the risk conclusions determined in the risk analysis or because these articles were published after the WDNR had conducted its literature review. WDNR and EPA do know that adverse effects from PCBs can occur in other mammals besides mink, thereby indicating that mink habitat is not specifically of concern, but whether there is habitat that may be used by any mammals. An additional article related to the toxicity of PCBs in bald eagles is Kaiser et al., 1980. Additional articles related to the toxicity of PCBs in mink include: Leonards et al., 1995; Halbrook et al., 1999; Hochstein et al., 1998; Backlin et al., 1998; Shipp et al., 1998; and Brunstrom et al., 2001. Articles related to the toxicity of PCBs in other mammals (i.e., otters, polecats) include: Behnisch et al., 1997; Leonards et al., 1994; Bergman et al., 1994; Davis, 1992; Elliott et al., 1999; Harding et al., 1996; Harding et al., 1999; and Hugla et al., 1998.

### References

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## 3.2.5 Weight of Evidence Approach

### Master Comment 3.17

WDNR received comments that the BLRA significantly overestimates current and future ecological risks presented by the Lower Fox River and Green Bay because the BLRA does not use the full weight of evidence in quantifying risks for decision making.

### *Response*

WDNR acknowledges that numerical weighting of lines of evidence is a type of evaluation that was not used, but this is not the only weight-of-evidence approach. Few if any Superfund sites have not used this quantitative weight-of-evidence approach proposed by Menzie et al. (1996) in their risk characterization. However, although a numeric evaluation is intended to be more quantitative and explicit in the methods of risk ranking, the rationale for the determination of weighting factors assigned to each measurement endpoint was not clearly described or defended by BBL. Additionally, some of the weighting factors described in the text were incorrectly recorded in the tables used to summarize numerical scores.

#### Reference

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# 3.3 Peer Review Process and Response

### Master Comment 3.18

Commenters stated that WDNR's HHRA and the BLRA appear to have responded to few, if any, of the AEHS peer review panel's recommendations.

### Summary of Human Health Comments

At the request and funding by the FRG, the AEHS conducted a peer review (dated June 29, 2000) on both the Pre-Draft BLRA and the FRG human health assessment (Exponent, 2000). Four general "critical findings" were made regarding the human health assessments:

1) Significant differences between the WDNR and FRG results undermine confidence in input assumptions and procedures.

2) Neither risk assessment addressed the significant potential for prenatal or perinatal effects (e.g., effects to the fetus or nursing infant). There

is also the need to evaluate neurological/developmental effects from short-term, high-level exposure.

3) FRG conducted a stochastic approach while WDNR employed point estimates. The comment did not indicate one method being superior to the other; however, the stochastic techniques were not adequately described and in some cases not appropriate.

4) The FRG assumed much lower fish ingestion rates and lower PCB concentrations than the WDNR.

More specific comments (many related to the comments above) included the following:

1) "The problem with the RETEC report is that it lacks proper style and format." AEHS commenters did not like the extensive use of acronyms and "boilerplate" text.

2) The FRG assumed much lower PCB concentrations in fish than the WDNR as a result of: (1) the use of fillet data only (WDNR used skin-on); (2) omission of carp and other bottom feeders from data set; and (3) erroneous assumptions in data distributions used in stochastic modeling.

3) Neither risk assessment considered pregnant women or nursing infants as sensitive subpopulations.

4) WDNR did not evaluate anglers that might use different preparation methods (e.g., reduction factor is low) or consume whole fish – this may underestimate PCB concentrations. However, WDNR did not assume declining fish concentrations – which may overestimate PCB concentrations.

5) WDNR did not weight the fish data according to fish species preferred for consumption.

6) Use of fish tissue data from a 20-year time frame may present problems with data consistency and quality. Use of more recent fish data in the WDNR focused assessment allows better comparison to results of FRG assessment.

7) Higher fish consumption rates used by WDNR (based on Wisconsin and Michigan studies) are reasonable.

8) WDNR assumes that all recreationally caught fish are from the Lower Fox River and Green Bay, which is not supported by the survey data.

## Response

In the 2001 draft BLRA, the specific concerns of the AEHS were addressed. Specific responses are as follows:

1) General Comment 1 does not require a specific response, but responses to other comments address several of the inconsistencies between WDNR's assumptions and FRG's assumptions. Responses to General Comments 2, 3, and 4 are provided below.

2) The commenters stated that WDNR did not evaluate the potential for prenatal or perinatal effects from PCB exposure. ATSDR's Toxicological Profile for PCBs (2000) provides detailed information on the toxic effects of PCBs to fetuses, infants, and children (refer to Section 3.7). This document emphasizes the fact that predicting effects is extremely difficult because there are so many variables. There are critical periods of structural and functional development during both prenatal and postnatal life, and a particular structure or function will be most sensitive to disruption during its critical period. There are no generally accepted methods to quantify PCB effects for *in utero* exposures or to nursing infants. However, WDNR qualitatively discussed effects of PCBs to the fetus, infant, and child by summarizing the results of various epidemiological studies.

3) The commenters also commented that WDNR did not evaluate neurological/developmental effects from short-term, high-level exposure. While it is possible to evaluate the effects of PCBs to pregnant and nursing women using a shorter exposure duration, it is difficult to quantify the effects this exposure may have on the fetus or infant. Once again, WDNR discusses these types of effects qualitatively in the literature review.

4) The point estimate approach was selected over stochastic modeling for the Pre-Draft BLRA. It includes a wide range of calculated results for the two most sensitive receptors, the recreational angler and the high-intake fish consumer. Two RME scenarios have been assessed; one using upper-bound concentrations and the second using average concentrations, and a CTE scenario was assessed. Furthermore, the focused evaluation of PCBs from fish ingestion explored a wide range of exposure scenarios incorporating various intake assumptions and PCB concentrations. As part of the focused evaluation, a probabilistic risk assessment of exposure assumptions for the recreational angler and high-intake fish consumer was conducted and was summarized in the Pre-Draft BLRA Section 5.9.6 and detailed in Appendix B1. The probabilistic evaluation analyzed the influence of variability by developing probability distributions for exposure parameters including fish concentration, fish ingestion rate and exposure frequency,

reduction factor, exposure duration, and body weight. WDNR and EPA feel the range of evaluations presented in this assessment sufficiently illustrates potential risks for average to high-end receptors. Importantly, EPA guidance specifies that point estimates of risk be used as the principle basis for decisions regarding the need for remedial action at a site (p. 5-120).

5) Commenters stated that WDNR's fish ingestion rates and predicted fish PCB concentrations were higher than those used by FRG. Selection of fish ingestion rates was based on literature as well as communication with various Agency personnel. The use of the two West et al. (1989, 1993) studies for exposure estimates is supported by the fact that these are regionally relevant data and these studies were specifically discussed in detail in the *EPA Human Health Exposure Factors Handbook* (EPA, 1997). Ingestion rates that are derived from studies conducted in an area where fish consumption advisories are in place are not representative of baseline conditions, which is the goal of the Pre-Draft BLRA.

Regarding the fish tissue PCB concentrations, WDNR based its representative concentrations on static (rather than declining) tissue levels. An assumption of declining fish concentrations would have to be well supported by the data in order to be certain that human health was being adequately protected. An extensive time trends analysis was performed that indicated that fish tissue concentrations were not consistently declining for species that are routinely consumed by humans. In the absence of statistical confirmation that tissue concentrations were declining, exposure concentrations were assumed to be static, which resulted in higher concentrations that those predicted by FRG.

Responses to some of the specific comments are also provided.

1) Comment does not require response.

2) Comments do not indicate that the fish PCB concentrations used by WDNR are overly conservative, just that they are much higher than the concentrations used by FRG. Comments supported some of WDNR's methodologies. We believe it is appropriately conservative to include skin-on fillet data and data from bottom-feeding fish such as carp in the data set. The assessment must address populations of fish consumers that eat different types of fish and use a variety of preparation methods. The justification for using static values rather than declining concentrations was provided in the response to General Comment 4.

3) Consideration of pregnant women and nursing infants was not quantitatively addressed in either the WDNR or FRG risk assessments. These exposures were not quantified because guidance is not available

and there is a large degree of uncertainty when attempting to estimate such intakes. This subject was discussed in more detail in the response to General Comment 2.

4) While WDNR did not consider fish preparation methods that have little reduction effect on the PCB concentrations, they did examine a wide range of fish consumption scenarios intended to represent RME. Use of lower reduction factors may be balanced out by use of more upper-bound representation of fish PCB concentrations.

5) Fish data were not weighted according to fish species preferred for consumption. This approach is protective of subpopulations that consume "less preferable" species, such as carp and other bottom feeders. People do eat carp and this is demonstrated by the number of websites dedicated to finding and preparing carp for human consumption. Examples of these websites include: www.carpanglersgroup.org, www.carp.net, www.carpuniverse.com, and www.carpdreamfishing.com.

6) WDNR included all fish tissue data that were available in the baseline assessment in an effort to be thorough. It was recognized, however, that data collected so long ago were of questionable quality. Therefore, the focused assessment provided an evaluation of data from the most recent decade of sampling. Conducting a variety of data evaluations enabled us to look at a range of results.

7) This comment indicates that the fish consumption rates used by WDNR (based on Wisconsin and Michigan studies) are reasonable. While no response is required, it might be important to note this third-party comment, especially in light of the other comments received, that these rates are not representative of the study population.

8) While it is likely true that anglers would not consume sport-caught fish that is entirely from the Lower Fox River and/or Green Bay, this is a conservative assumption. It also provides a basis for comparison of the risks from each reach and zone.

## Summary of Ecological Comments

For the ecological risk assessment, four general comments, or "critical findings," were made by AEHS:

1) This comment indicates WDNR ignored field studies and chose the most conservative values in most cases.

2) Commenters stated that, regarding the process for ecological evaluation defined by EPA, WDNR addressed primarily steps 1 and 2, with little development of other steps. It is the conclusion of the panel

that, if these steps were integrated, a more scientifically defensible risk assessment would result.

3) Commenters stated that in handling data, WDNR utilized the 95 percent UCL in a normal distribution, calculating this value with data collected over approximately a 10-year period. Without appropriate statistical analysis, a normal distribution cannot be assumed.

4) Commenters stated that TRVs from WDNR are very conservative and it is unclear in some cases, for the basis of the TRVs.

## *Response*

1) The February 1999 draft of the BLRA did not include a discussion of field studies, but currently the BLRA does include a discussion of field studies within the risk characterization section (Section 6.5.4).

2) The February 1999 draft of the BLRA did not include a discussion of field studies, population levels, USFWS NRDA investigations, and most importantly exposure modeling for birds and mammals had not been conducted or evaluated. The current version of the BLRA does include a discussion of each of these.

3) The 95 percent UCL calculation was modified to be specific to the data distribution – either normal or lognormal. If the data distribution did not fit either a normal or lognormal pattern, the normal 95 percent UCL was used as a default.

4) In the interim period between the 1999 draft and the present draft of the BLRA, much time was spent collaboratively selecting and better documenting the selection of the site-specific TRVs.

### References

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# 3.4 Sediment Quality Thresholds

## Master Comment 3.19

Commenters stated that the October 2001 BLRA calculates inappropriate and overly conservative SQTs based on unrealistic human health scenarios and conditions present in a different reach of the River than OU 1.

## *Response*

WDNR and EPA disagree with this comment. Multiple SQTs are developed and model-calibrated in each individual reach. From the SQTs, a range of remedial action levels were modeled and examined for achieving risk reduction by individual OU. The WDNR and EPA believe that the method used to generate SQTs is consistent with the NCP guidance and the recommendations of the NRC, and pertinent federal guidance. See also *White Paper No. 11 – Comparison of SQTs, RALs, RAOs and SWACs for the Lower Fox River*.

## Master Comment 3.20

The WDNR received comments related to how sediment to water ratios were calculated and used in determining SQTs. One comment suggested that the limited data presented for developing the sediment to water ratios indicated that there could be a trend in decreasing ratios moving downstream (ratio around $10^{-6}$ upstream of Little Rapids; around $10^{-5}$ below Little Rapids). This commenter further asserted that this change, if real would seem consistent with the upstream sections being the source, releasing PCBs to the surface water, hence lower ratios, while downstream is a sink with higher (non-equilibrium) PCB concentrations in the water carried down from upstream.

Another comment focused on the data presented in Table 7-7. This table lists different sample years for the sediment and water data within each reach and, therefore, indicates that the water and sediment data are not synoptic. The commenter noted that this situation raises specific concerns including:

1) Whether and how sediment and water collections were matched?

2) How much of the variation in water (filtered) was related to collection location or seasonality or flow?

3) Were the sediment concentrations based on point (0- to 10-cm) samples?

4) Was the sampling distributed over the entire reach or focused on particular areas?

5) What is represented by the "average" (arithmetic or geometric mean of all sample data)?

6) How are variations in organic carbon content of sediments and water (dissolved and suspended matter) incorporated into the ratio calculations? The implication by the statement on page 7-8, paragraph 3, which notes that Zone 2 has "different total organic carbon (TOC) concentrations in sediment", is that the model has been revised to incorporate TOC as a variable.

7) Was the maximum ratio based on the highest sediment and lowest water concentration (or highest to highest)? Note that if the maximum ratio is based on the ratio of the highest values, then the ratio is not really a "maximum" – likewise for minimum and mean ratios.

### *Response*

Because the sediment and water data were not collected synoptically and because there are few data available, it can not be determined whether there are any trends in the sediment-to-water ratio in moving from upstream to downstream locations. Regarding the specific comments related to Table 7-7, questions 1 through 4 cannot be answered from the data that were extracted from the FRDB. Rather, these questions would require a detailed investigation of original reports that were reviewed to compile the FRDB. To answer question 5, the average concentrations represent arithmetic mean concentrations. To answer question 6, TOC was not considered in the calculation of the sediment-to-water ratio. Water concentrations used for the calculation of this ratio were based on estimated total (filtered plus particulate) concentrations. Reach- and zone-specific TOC concentrations were, however, used as an input in the calibration of the FRFood Model – the model that was used in reverse to calculate SQTs. To answer question 7, the sediment-to-water ratio represented in the "Maximum" column resulted from a comparison of maximum water and maximum sediment concentrations. The same rationale was used for the calculation of minimum and mean sediment and water ratios.

## Master Comment 3.21

A commenter expressed the opinion that the conceptual representation of the PCB problem at the Lower Fox River and Green Bay Site is factually inaccurate and that the Proposed Plan and supporting technical documents overstate the PCB problems.

## *Response*

WDNR and EPA disagree with this statement. The characterization of the Site defines sources as well as current Site information and risks. The technical evaluation of remedial technologies is the appropriate level of detail needed at this point in the Superfund decision-making process. Additional sample collection and analysis will be conducted as part of the remedial design phase.

# 4 RAOs, SQT, and RAL Selection

## 4.1 RAOs

### Master Comment 4.1

Several commenters, in both public and private sectors, expressed concern about the expression of RAOs in the FS and in the Proposed Plan. There were numerous questions about the intent of the RAOs, how RAOs were used, and in some cases questions concerning the wording of the RAOs.

### *Response*

WDNR and EPA evaluated the RAOs in the Draft FS and Proposed Plan. To be consistent in final documents, the RAOs have been formulated as follows:

- *RAO 1: Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay.*

  This RAO is intended to reduce PCB concentration in surface water as quickly as possible. The current water quality criteria for PCBs are 0.003 ng/L for the protection of human health and 0.012 ng/L for the protection of wild and domestic animals. Water quality criteria incorporate all routes of exposure assuming the maximum amount is ingested daily over a person's lifetime.

- *RAO 2: Protect humans who consume fish from exposure to COCs that exceed protective levels.*

  This RAO is intended to protect human health by targeting removal of fish consumption advisories as quickly as possible. WDNR and EPA defined the expectation for the protection of human health as the likelihood for recreational anglers and high-intake fish consumers to consume fish within 10 and 30 years, respectively, at an acceptable level of risk or without restrictions following completion of a remedy.

- *RAO 3: Protect ecological receptors from exposure to COCs above protective levels.*

  RAO 3 is intended to protect ecological receptors like invertebrates, birds, fish, and mammals. WDNR and EPA defined the ecological expectation as the likelihood of achieving safe ecological thresholds for fish-eating birds and mammals within 30 years following remedy completion. Although the FS did not identify a specific timeframe for evaluating ecological protection, the 30-year figure was used as a measurement tool.

- *RAO 4: Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan.*

  The objective of this RAO is to reduce the transport of PCBs from the River into Green Bay and Lake Michigan as quickly as possible. WDNR and EPA defined the transport expectation as a reduction in loading to Green Bay and Lake Michigan to levels comparable to the loading from other Lake Michigan tributaries. This RAO applies only to River reaches.

- *RAO 5: Minimize the downstream movement of PCBs during implementation of the remedy.*

  A remedy is to be completed within 10 years.

## Master Comment 4.2

Several commenters indicated the remedy will not achieve the RAOs due to background conditions. Further, the RAOs in the Proposed Plan compared to the FS have two changes – the phrase "as quickly as possible" has been added to three of the five RAOs and the FS references to COCs have been removed. Another commenter indicated that RAOs constitute goals and should not be qualified by "to the extent practicable."

## *Response*

WDNR and EPA have reviewed the documents and have addressed all language inconsistencies. Concerning the achievement of the RAOs, the Agencies believe the remedy can achieve RAOs 2 and 3 dealing with fish consumption advisories and impacts to the ecosystem. Concerning RAO 4, which deals with transport from the Lower Fox River to Green Bay, the Agencies believe this will be achieved by active remediation. The term "as quickly as possible" was included in the RAOs in the Proposed Plan to indicate that the regulatory agencies believe the RAOs should be achieved relatively soon, rather than being delayed.

RAO 1, which addresses achieving water quality criteria, is the only RAO that uses the term "to the extent practicable." This purpose of the RAO is to stress the need for remediation to reduce PCBs in the water column as well as to attempt to meet water quality criteria. The term "to the extent practicable" was added due to the realization that background levels entering the study area (i.e., the water from Lake Winnebago) cannot be accurately determined due to limitations of available analytical methods. Surface water quality standards in Wisconsin are 0.003 ng/L for protection of human health and 0.12 ng/L for the protection of wildlife. The 1 ppm action level will result in a reduction in surface water PCB concentrations of greater than 90 percent within the Lower Fox River.

## Master Comment 4.3

Some commenters suggested the addition of a sixth RAO concerning habitat enhancement. The premise offered was that any final remediation strategy for the Lower Fox River achieve a balance between the benefits of sediment remediation and other ecosystem restoration alternatives.

### *Response*

WDNR and EPA both believe that environmental restoration is a critical component to the remediation of the Lower Fox River and Green Bay. It is also a requirement of the Superfund law. It is the Agencies' position that removal of PCB-contaminated sediment is the first, and most important step, for environmental restoration in the Lower Fox River.

Habitat restoration is the function of the NRDA program, which has been an integral part of the overall Lower Fox River management. The state, working with the federal resource trustees, has already begun working with various responsible parties to initiate restoration activities. However, it is also important to note that the law requires that these restoration activities must be undertaken with the trustee agencies and not the remediation agencies through the NRDA process. As such, the restoration actions are not part of the ROD. It is the aim of the state to achieve a single global settlement with all responsible parties, as well as the trustee agencies, so that a comprehensive agreement is achieved that covers both remediation and restoration activities.

## Master Comment 4.4

RAO 4 states that an objective of remediation is to reduce transport of PCBs from the Lower Fox River into Green Bay. Some commenters stated that this RAO is arbitrary in that it excludes other remedial alternatives from consideration. They contend that modeling supported by WDNR predicts no measurable benefit in the Bay from remediation of the River.

### *Response*

WDNR and EPA strongly disagree with this comment. The intent of RAO 4 is to reduce the PCB transport to Green Bay from the Lower Fox River. An objective of this RAO is to remove the PCBs from the River where they are more readily accessible for remedial management, rather than wait until the contaminants have migrated out into the Bay where they are more dilute and more expensive to remediate. As is discussed in Section 5.6 of the RI, anywhere from 125 to 220 kg (275 to 485 pounds) of PCB mass is exported from the Lower Fox River to Green Bay on an annual basis. Furthermore, based on the models used by WDNR in evaluating transport from the River to the Bay, it is estimated that there will be a greater than 90 percent reduction in annual loading of PCBs to the Bay if the remediation in the Proposed Plan is implemented.

Reduction of the contaminant loading from the Lower Fox River to Green Bay and Lake Michigan is a fundamental goal of this Superfund action, and active remediation in the River and Bay will reduce long-term risks to human health and the environment. The need for remediation is well supported by the current risks documented in the BLRA from PCBs in the Lower Fox River and Green Bay. In addition, RAO 4 directly supports the Lake Michigan Lake-wide Management Plan's (LaMP's) (EPA, 2000) basic principle to: "Reduce loadings and emissions of LaMP critical pollutants to the Lake Michigan ecosystem and remediate contaminated sediments within the 10 Areas of Concern in the Lake Michigan basin; utilize the LaMP process to develop reduction targets (building on the Lake Michigan Mass Balance Study and the Binational Strategy); and achieve substantial reductions in human and ecological health risks in the basin." While treatment is not proposed herein, reduction of mobility can be achieved through removal of contaminants from the environment and placing them in a contained structure (i.e., landfill).

Contrary to the comment received, WDNR's modeling does show improvements to the Bay. For example, as documented in the FS Table 8-10, with a combination of a 1 ppm action level for the River and in the Bay reduces the time to the CTE cancer risk of $10^{-4}$ to 3 years. This compares to no action in the River and Bay taking 83 years to achieve this risk level.

#### Reference

EPA, 2000. *Lake Michigan Lake-wide Management Plan*. United States Environmental Protection Agency Website: http://www.epa.gov/grtlakes/lakemich/.

### Master Comment 4.5

Several commenters noted that the any remedial plan for the Lower Fox River must also protect Lake Michigan, and not just local environments.

### *Response*

WDNR and EPA believe this plan goes a long ways in protecting Lake Michigan in that the remedy in the ROD will significantly reduce the single largest source of PCBs being discharged into Lake Michigan. This effort along with the combined effects of successful remediation at other remedial sites along the shoreline and water discharging to Lake Michigan will contribute to the lake's overall protection.

## 4.2 SQTs and SWACs

### Master Comment 4.6

A commenter stated that the Proposed Plan applies SQTs as an RAL everywhere in the sediment, not at the surface.

## *Response*

Based on comments from the EPA's National Remedy Review Board, the Agencies defined a range of cleanup levels, known as the RALs rather than the single risk-based SQT as was presented in the WDNR February 1999 draft RI/FS. As such, all sediment exceeding a specific RAL was identified for remediation. Application of an RAL to sediment at depth recognizes the Agencies' position that future conditions can cause PCBs at depth to become exposed to the water column or biota. The effects from removal, containment, or non-removal of contaminants and potential exposure from surface sediments are reflected in modeling estimates for evaluated receptors (FS Section 8).

## Master Comment 4.7

Commenters stated that the Proposed Plan applies the 0.25 ppm SQT, derived from OU 4 to the entire River rather than calculate the risk that PCB-containing sediments present for the biota for each reach. The Proposed Plan should consider different action levels for different reaches and the sediment-to-water ratios derived for OU 4 should not be applied to the whole River.

## *Response*

In selecting the appropriate action level for OU 1, WDNR and EPA applied an approach that balanced risk reduction for human health and the environment, as well as the residual SWAC and the resulting human health and ecological SQT for each OU. For determination of RALs, WDNR and EPA also considered cost as well as long-term effectiveness. For OU 1, the 1 ppm action level resulted in the most appropriate level of risk reduction. Sediment to water ratios were developed for all four reaches of the River and for Green Bay. The general term used to estimate SQTs was not from OU 4, as the commenter implies, but rather a value of 10- was determined to be a good estimation of the range of values observed. As documented in Section 7 of the BLBA, sediment to water ratios averages ranged between 10-4 to 10-7 for all operable units, and average 10-5 in OUs 3 and 4, to 10- in OUs 1, 3, and Zone 2 of Green Bay. See Section 9.6 of the Proposed Plan and *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

## Master Comment 4.8

The differences between SQTs, SWACs, and RALs were commented on by numerous parties. How the SQTs, derived in the risk assessment, translated into SWACs, the multiple RALs examined in the FS, and how ultimately the Agencies selected an RAL of 1 ppm was questioned. Commenters stated that the Proposed Plan calculates a single SQT for one reach and then applies the number uniformly to all reaches, though all areas do not contribute equally to the PCB exposure.

## Response

PCBs were identified as the principal contaminant causing or potentially causing risk to human health and the environment. In order to translate risks to human health and the environment into a cleanup goal, it became necessary to relate risks with sediment concentrations of PCBs. Three separate but related risk and remedial action numbers were generated in the BLRA and FS. These are as follows:

- **Sediment Quality Thresholds** were developed that linked single-point concentrations of PCBs to specific risks to human health and the environment.
- **Surface-Weighted Average Concentrations** related the risk estimates developed in the SQT to the entire area of the OU (e.g., Little Lake Butte des Morts, De Pere dam to Green Bay).
- The **Remedial Action Level** is the engineering design level around which the removal or containment alternative is structured. The RAL is selected so that when the cleanup is achieved, the SWAC is also achieved.

The development and relationship of SQTs, SWACs, and RALs are detailed in Section 7 of the BLRA, Section 5 of the FS, and are further discussed in *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

SQTs should be considered as receptor-specific point estimates (i.e., they are calculated for a specific sediment location, pathway, and receptor). The SQTs themselves are not cleanup criteria, but are a good approximation of protective sediment thresholds and were considered to be "working values" from which RALs were selected. SQTs do not vary by OU, but may vary by Superfund site, given the type of contamination, the types of species, site-specific exposure potential, the location-specific information available at a specific Superfund site, etc. WDNR and EPA believe that the SQTs developed for the Lower Fox River and Green Bay Site apply site-wide.

The SWAC is the concentration of PCBs in sediments calculated as an average over the entire surface area of an OU. In the FS, SWACs were calculated for baseline risk and for post-remedial actions based on a series of evaluated RALs (e.g., 0, 0.125, 0.25, 0.5, 1, 5 ppm). The current or residual SWAC could be compared to the SQTs to determine which species were or were not at risk over the entire OU. Figure 1 in *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River* provides a convenient reference comparing the SQTs, SWAC, and RALs.

Commenters often appeared to have confused the SQTs and the RAL of 1 ppm selected by WDNR and EPA for each OU. The distinction is articulated in *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*. SQTs were developed for individual receptors at varying risk levels for each OU in Section 7 of the BLRA. The RAL was selected based upon several considerations for each reach that included: (1) residual SWAC; (2) time to achieve risk management goals; (3) ability to achieve all RAOs; (4) overall contamination cost of the remedial action; and (5) other considerations. A further explanation and rationale for the selected RAL is discussed in the ROD.

### Master Comment 4.9

RALs developed in the October 2001 Draft FS based on SQTs does not comply with NCP, as SQTs were derived from modeling of an average set of conditions in one reach with greatest risk and applied to all reaches. These commenters also argued that the SQT applies to the top 10 cm, and should be translated to SWAC.

### *Response*

WDNR and EPA strongly disagree with this comment. Development of the SQTs, SWACs, and RALs is fully in compliance with the NCP, and is responsive to the NAS Board's recommendation of developing site-specific risk assessments and cleanup values. The commenter is incorrect in stating that SQTs were developed in one reach and applied to all reaches. The SQTs were developed and tested for all reaches. Furthermore, the SQT is applied only in the areas where organisms are exposed (i.e., the top 10 cm), and the SWAC is compared directly to the SQTs for both human and ecological receptors. See also the response to Master Comment 3.19 in Section 3.

## 4.3 Selection of RAL

### Master Comment 4.10

Several commenters expressed agreement with the Proposed Plan Alternative C, which includes the removal of sediment with PCB concentrations greater than 1 ppm RAL using a hydraulic dredge, followed by off-site disposal of the sediment.

### *Response*

Comment noted.

### Master Comment 4.11

A commenter expressed disagreement with the Proposed Plan monitored natural recovery plan for OU 2 and indicated that "hotspots" within the OU should be remediated to a lower RAL (0.25 or 0.125 ppm) even if the unit cost to remove PCBs were significantly higher.

### *Response*

The WDNR and EPA do not support the need for active remediation in OU 2 and believe MNR is the appropriate response action. Remediation to the level suggested by the commenter would not likely result in a substantial risk reduction. This is because, in part, it would be, at best, difficult to achieve concentration reductions for many of the OU 2 deposits, due to bedrock underlying contaminated sediments. Furthermore, the mass of PCBs (109 kg) and volume of contaminated sediment (339,200 cy) for these deposits are relatively small when compared to the PCB mass and contaminated sediment volume in the rest of the River. The current SWAC for OU 2 is 0.61 ppm. Furthermore, two deposits, N and DD, within this OU account for over 50 percent of the PCB mass. The WDNR has already addressed Deposit N and Deposit O. The Agencies will decide on Deposit DD when the ROD for OUs 3 through 5 is released.

### Master Comment 4.12

Some commenters supported the cleanup standard of 0.25 ppm which was included in the February 1999 RI/FS.

### *Response*

WDNR and EPA selected the 1 ppm RAL based on an evaluation of action levels with the residual SWAC for each OU and the ability of the action level to meet the RAOs. The Agencies in particular considered the time to achieve removal of fish consumption advisories, as well as the reduction in impacts to the ecosystem. The 1 ppm RAL is the best mechanism for achieving these goals. This is consistent with the process identified in the Proposed Plan. WDNR and EPA do not believe this is inconsistent with what was called for in the 1999 Draft RI/FS. The 1999 Draft RI/FS called for an action level of 0.25 ppm or a 0.25 ppm SWAC with neither being selected. The SWAC value resulting from the 1 ppm action level is 0.19 ppm in OU 1. For further discussion, please review the supporting document that explains the relationship of the RAL to the SWAC and *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

### Master Comment 4.13

Commenters stated the PCB sediment cleanup target must be strengthened and lowered to either 0.5 or 0.25 ppm PCBs. The commenter stated that more stringent cleanup levels have been chosen at other sediment sites such as Sheboygan. The commenters' opinion is that a lower hotspot cleanup level is needed to protect human health and to achieve the average sediment levels necessary to lift the fish consumption advisory. Other commenters suggested that the Proposed Plan applies a 1 ppm RAL to OU 1 based on factors other than risk.

## *Response*

WDNR and EPA carefully considered more and less stringent cleanup levels (RALs) before arriving at the 1 ppm level in the ROD. This cleanup standard is not arbitrary and the Agencies gave careful consideration to what is needed to be protective and meet the RAOs. The selection of the cleanup level is the outcome of a complete and scientifically based risk evaluation. In selection of the 1 ppm RAL, WDNR and EPA considered RAOs, model forecasts of the time necessary to achieve risk reduction, the post-remediation SWAC, comparison of the residual concentration to SQTs for human and ecological receptors as well as sediment volume and PCB mass to be managed, as well as the cost. This is discussed further in the ROD.

Multiple RALs were considered for each OU, no action, 0.125, 0.25, 0.5, 1, and 5 ppm. Model forecasts were used to compare the projected outcomes of the remedial alternatives using various action levels with the RAOs, primarily RAOs 2 and 3, which deal with protection of human health and the environment. On the basis of that analysis and to achieve the risk reduction objectives using a consistent action level, 1 ppm was agreed upon as the appropriate RAL.

In OU 1, the time needed to reach the endpoints for risk reduction varies by receptor from less than 1 year to an estimated 29 years. As was pointed out in earlier documents (e.g., the Proposed Plan), the upstream reach achieves risk reduction faster than does the area around the mouth of the River. The SWAC in OU 1 is a measure of the surface (upper 10 cm) concentration and would be 0.19 ppm if all material greater than 1 ppm can be removed. The SWAC value provides a number that can be compared to the SQTs developed in the BLRA. SQTs are estimated concentrations that link risk in humans, birds, mammals, and fish with safe threshold concentrations of PCBs in sediment. A comparison of the SWAC and SQT values shows that there is overlap of the various SQT values for recreational anglers, high-intake fish consumers, and wildlife, and the SWAC value for the OU 1.

## Master Comment 4.14

Commenters expressed the concern that the use of an RAL rather than a SWAC-based cleanup value weakens the connection between the remedy chosen for OU 1 and the risk caused by that reach.

## *Response*

WDNR and EPA have chosen to use the RAL-based approach for consistency with each OU. For all OUs, the resulting SWAC was evaluated to determine whether the RAL and resulting SWAC is protective of human health and the environment. The 1 ppm RAL and resulting SWAC for OU 1 does result in implementation of a remedy that is sufficient to meet this standard. Furthermore, since OU 1 is the furthermost upstream reach of the River, it inherently makes sense to ensure that the sediments in this reach will no longer be a continuing source to the downstream reaches. See also *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

## Master Comment 4.15

One commenter stated that the remedy of OU 1 in the Proposed Plan is too extensive in that the remedy requires the removal of all sediment with a PCB concentration greater than 1 ppm, regardless of depth, overlying concentration, or stability of sediment beds.

## *Response*

The commenter misconstrues the removal action in OU 1. The remedial footprint shown in Section 7 of the FS is based upon sediment concentrations of PCBs that exceed 1 ppm. It is inaccurate to represent that an area is targeted for removal where surface sediments do not exceed the Proposed Plan RAL. What is true is that within that remedial footprint, removal continues throughout the vertical profile until all sediments exceeding the RAL are extracted.

The stability of sediments in Little Lake Butte des Morts has not been established with sufficient certainty to ensure contaminants would remain permanently buried. Furthermore, it has not been evaluated, documented, or established that a thin layer of less contaminated material over more contaminated sediments make contaminants unavailable to the food chain.

## Master Comment 4.16

A commenter indicated that the remediation standard of 0.25 ppm for cleanup is arbitrary.

## *Response*

This comment is not clear. It is possible the person was referring to the February 1999 RI/FS. WDNR and EPA did use a range of RALs from 0.125 to 5 ppm in the FS. Derivation of the RALs, and corresponding SWAC are discussed in Section 5 of the FS. Remedial alternatives were constructed for each River reach or Bay zone in Section 7 of the FS, and were evaluated for cost, risks, and compared to the CERCLA threshold and balancing criteria in Sections 8 through 10. For the Proposed Plan, EPA and WDNR selected an RAL of 1 ppm based upon careful, deliberate consideration of the permanence, risk reduction, public acceptance, and costs presented in the FS.

The 1 ppm RAL cleanup standard is a risk-based cleanup standard and is considered protective. The 0.25 ppm level from the February 1999 RI/FS was a preliminary number considered both a resulting SWAC and a complete removal of that action level. The SWAC for a 1 ppm RAL as presented in the Proposed Plan actually produced a SWAC of 0.185 ppm for OU 1. Thus, if the comparison is to the original 0.25 ppm SWAC the cleanup standard is, on average, lower than the original preliminary cleanup number. Regardless of the comparison, the most current evaluation in the BLRA shows that the proposed cleanup standard is protective in any event. The proposed RAL will remove fish advisories in OU 1, while the 0.25 ppm RAL would remove fish advisories in a shorter period.

## Master Comment 4.17

Commenters suggested that the RAL of 1 ppm does not meet the human health and ecosystem goals of the remedial plan.

### *Response*

WDNR and EPA disagree with this comment. The basis for selection of the RAL was clearly identified in the Proposed Plan and is further explained in the ROD.

## Master Comment 4.18

One commenter expressed disagreement with the Proposed Plan's Alternative C2, which includes the removal of sediment with PCB concentrations greater than the 1 ppm action level using a hydraulic dredge, followed by off-site disposal of the sediment. The commenter expressed concern that with an RAL of 1 ppm, it will take 20 years to remove the walleye fish advisory and 29 years to remove the carp advisory, which is significantly higher than the upstream areas of the River that are cleaned to 1 ppm. The commenter supported a cleanup action level of 0.25 ppm, which would reduce the removal of the walleye advisory to 8 years and the carp advisory to 9 years.

### *Response*

As noted in Master Comment 4.12, the RAL of 1 ppm was derived by balancing multiple considerations. The nine evaluation criteria under CERCLA required WDNR and EPA to balance risk reduction against such factors as community acceptance, implementability, and permanence of the remedy, and with the overall cost of the remedy. Both more stringent and less stringent criteria were evaluated, but after consideration, the 1 ppm RAL was selected.

## Master Comment 4.19

One commenter suggested that a better way of evaluating sediment remediation areas would be to use an approach of PCB mass per unit area similar to that conducted on the Hudson River.

## Response

WDNR and EPA disagree with this comment. For Superfund sites, site-specific determinations are generally required. Conditions and characteristics as well as available data are critical considerations in how cleanup levels are determined as well as what cleanup levels are appropriate for each site. These considerations include impacted media and potential exposures, contaminant toxicities and concentrations, the nature of risks to human health and the environment, and the quality and type of available data. Specific characteristics for sediment sites also include horizontal and vertical contaminant distribution, sediment thickness and physical characteristics, relationships between media (i.e., sediments and ground/surface water, biota, and air), and potential for releases and exposures. These all factor into determination of the most effective and protective use of available information to estimate and measure potential site risks. For the Lower Fox River Site, an RAL defining a specific vertical and horizontal target area, combined with the SWAC, were determined to be the most appropriate, protective, and feasible approach in estimating and measuring site risks.

The suggestion by the commenter reveals a fundamental misunderstanding of the differences between the RAOs for the Lower Fox River and the Hudson River. The RAOs for the Lower Fox River specifically called out the protection of individuals and ecological receptors that eat fish. For the Hudson River, two general RAOs were developed pertaining directly to sediments: “reduce the inventory (mass) of PCBs in sediment that are or may be bioavailable, and minimize the long-term downstream transport of PCBs in the river.” The Hudson RAOs resulted in the selection of mass per unit area criteria for the selection of remedial areas. The Hudson Responsiveness Summary (EPA, 2002) acknowledged that the mass criteria do not allow for direct comparison with the sediment thresholds, nor to direct comparison to reduction in fish tissue concentrations. Given that, the Hudson approach is not appropriate to the Lower Fox River.

In addition, as part of the mass per unit area analysis, the commenter has mentioned thresholds to identify “hot spots” and “expanded hot spots.” The commenter has failed to include Deposit A under the expanded hot spot category as the mass per unit area estimated by the commenter is 3.7 grams per square meter ($g/m^2$), which is greater than the expanded hotspot threshold (3 $g/m^2$). Also, the commenter has mentioned on page 16 of the comments, “PCB mass per unit area for different sediment deposits, and then focus on those deposits with the most concentrated mass.” However, from the mass per unit area numbers provided by the commenter, it appears that surficial PCB mass over a particular reach has been simply converted to calculate PCB $g/m^2$. This approach appears to provide results that average the PCB mass across the entire reach and does not truly represent an area with the most concentrated mass.

### Reference

EPA, 2002. *Responsiveness Summary – Hudson River PCBs Site Record of Decision*. Prepared for United States Environmental Protection Agency, Region 2 and United States Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc. January.

# 5 Technical Evaluation and Remedial Alternative Development

## 5.1 Effectiveness of Dredging

### 5.1.1 Sediment Technologies Memorandum

#### Master Comment 5.1

Appendix B of the FS, the *Sediment Technologies Memorandum*, provides a review of several dredging projects.  Comments were submitted that suggest that the review examined only projects that dealt with mass removal, did not address the issues of risk reduction, short-term effectiveness, and applicability to the Lower Fox River.

#### *Response*

The commenter misrepresents the objectives and findings of the *Sediment Technologies Memorandum*.  A continuing theme presented by opponents of removal options for the Lower Fox River is that historical environmental dredging programs have all failed to reduce risks to human health and the environment.  In comments submitted to both the 1999 and 2001 RI/FS documents, the commenters list "failures" in several environmental dredging projects, without presenting the stated construction and environmental management goals.  Citing a limited number of cases, these critics suggest that dredging has limited exposure reduction benefits, and may increase rather than decrease contaminant exposure.  However, their assertions never examine the underlying reasons for short-term deficiencies (e.g., poor dredging design, contractor quality control, etc.), and the long-term positive effects of removal actions at other contaminated sediment sites are ignored. This application of risk goals ex post facto to remedial programs that were managed otherwise is misleading.

The *Sediment Technologies Memorandum* documents the process of acquiring all management and construction documents related to a project.  The projects represented were not "carefully screened," as is suggested by the commenter. Rather, only those projects that had clear and adequate documentation associated with the purpose and outcome were used.  The commenters fail to acknowledge that over 60 projects were screened for data adequacy before settling on the 20 projects reviewed.

The FS Appendix B, case study review, addressed two questions:  (1) whether dredging can physically be implemented and meet the target performance goals established for a project, and (2) whether long-term risk reduction benefits (i.e., reduced fish tissue concentrations) were observed over time.  To answer these questions, each case study was evaluated for both short-term and long-term goals. Both questions are valuable when determining the implementability and feasibility of dredging as a possible remedial alternative. Short-term evaluations looked at monitoring parameters such as: surface water quality during dredging, air quality during dredging, surface sediment concentrations immediately after dredging, the contaminant mass and/or volume of sediment removed when compared to design specifications, and perceived success of the equipment used when compared to Site conditions. Long-term evaluations looked at monitoring parameters such as: surface sediment concentrations, bioassay toxicity, and fish tissue concentrations over time.

The success of long-term risk reduction can be quite subjective and the outcome of site-specific projects can be viewed in many different ways depending on the criteria applied by the evaluator. An example of the misrepresentation the *Sediment Technologies Memorandum* sought to address is included within the FRG's comments to the 2001 RI/FS. Within their Table 1, several projects, including the Fox River Deposit N, are compared to "Post Remediation Confirmation PCB Levels," with the inference that these failed to meet cleanup goals. In all of those cases listed, the project was intended to be a mass removal, not removal to a cleanup goal. Those projects were successful from the standpoint of their environmental management and construction goals.

In reviewing outcomes at other Superfund sites, it should be noted that PCB residual concentrations actually attained at these other locations were dependent, in part, on the cleanup goal set there. For example, at the Manistique River Site, the cleanup goal was to remove 95 percent of PCB mass and achieve an overall average residual concentration of less than 10 ppm after dredging. Therefore, the residual PCB concentration at this location should not be expected to be 1 ppm since the targeted level was actually higher. Another example, the Lower Fox River pilot demonstration project at Deposit N, the cleanup goal was to remove the impacted sediment down to within 6 inches of bedrock, understanding that the final 6 inches would be difficult to dredge effectively. With the bulk of the PCB mass removed in an "unstable section of the Lower Fox River, long-term risk reduction via reduction exposure is anticipated."

To standardize the way WDNR perceived "risk reduction success" of individual projects and eliminate potential bias, WDNR applied the values and goals established by the local regulators and communities directly managing a particular project when determining "success." WDNR did not "mask the results of the 20 case studies" as perceived by commenters, but instead, described the current status of all 20 projects relative to risk reduction. Some projects are inconclusive (with no trends observed), some projects show declining trends but more data and time are needed to validate the trends, and some projects are considered to have achieved adequate risk reduction by local regulators.

Finally, an important finding of the *Sediment Technologies Memorandum* was the inadequacy (or lack thereof) of the monitoring programs associated with the post-remedy. A common shortcoming of many sediment remedies, whether it is dredging, capping, or natural recovery, is whether or not the monitoring program could detect trends of risk reduction to biotic resources over time. Another conundrum is that many of the large-scale dredging projects cited by commenters have been completed in the last 10 years, and therefore not enough time has passed to filter out natural temporal variability in site conditions and populations. This observation was also stated by the NRC as "Long-term monitoring results are sparse, in part because most active management efforts were conducted within the past 5 years, and only a few were conducted as long as 10 years ago…there are significant disincentives to conducting long-term monitoring…and available monitoring information has been gathered mainly during implementation…" (NRC, 2001). In some cases, multiple lines of evidence may be needed to detect trends of post-remedy risk reduction.

In terms of application to the Lower Fox River, Appendix B of the FS also looked at short-term goals to assess the implementability of dredging as a remedial alternative. Based on our findings, it appeared that dredging could feasibly be implemented and still meet the design criteria set forth in the projects (i.e., residual concentrations, air quality, surface water quality, community support). Based on these "positive" findings, dredging was retained as a possible alternative in the Lower Fox River FS. Appendix B of the FS also looked at long-term goals of risk reduction to assess the long-term effectiveness of dredging remedies. Based on WDNR's findings, it appeared that long-term risk reduction has been achieved at some projects, but others still required more time, and/or better monitoring to confirm. In some cases, different cleanup levels and/or remedies may be required to achieve long-term risk reduction in a reasonable timeframe.

### Reference

NRC, 2001. *A Risk-Management Strategy for PCB-Contaminated Sediments*. Committee on Remediation of PCB-contaminated Sediments. National Research Council, National Academy of Sciences.

## Master Comment 5.2

Commenters asserted that Appendix B did not accurately represent the data from some of the case study sites, specifically whether risk-based criteria were achieved. They contended that despite attempts to over-dredge and with cleanup passes, the removal actions did not achieve risk reduction for several of the projects listed.

### *Response*

Several of the remedial dredging projects that commenters claimed did not achieve risk reduction involved sites where contaminated sediments were underlain by hard substrate. This site-specific condition prevented over-cutting of contaminated materials, a strategy that could have led to significantly lower PCB residuals. These same issues, projects, and appropriate responses can also be found in the Hudson River Responsiveness Summary Master Comment 579.

WDNR notes that it may not always be feasible to use over-dredging to improve removal efficiency. As noted at Deposit N, the hard substrate prevented over-dredging. However, as identified in the FS, over-dredging of sediments will be accomplished only when possible. There are several areas within the dredge footprint of the River where sediments will be dredged to hard bottom that eliminates the need for over-dredging. The residual contamination depends on a number of factors that include depth and type of materials underlying the dredge footprint, average PCB concentration of sediments, depth of cut, and cleanup goal for project. These conditions are site-specific and vary by project. Results from the *Sediment Technologies Memorandum* (FS Appendix B) indicate that dredging can be implemented in an effective way if the technology is designed and managed appropriately for the site conditions. Recent advances in dredge head construction and positioning technology enable accurate removal of sediment layers with minimum incidental over-dredging to achieve target goals. As stated in the FS, 17 of the 20 projects mentioned in Appendix B met the short-term target goals that include sediment excavation to a chemical concentration, mass, horizon, elevation, or depth compliance criteria. Seven projects designed "over-dredge" into the project plans. In five out of seven cases, where over-dredge could occur, target goals were met.

This issue was also addressed in the Hudson Responsiveness Summary Master Comment 579, and Hudson River Responsiveness Summary White Paper 312663, Post-Dredging PCB Residuals.

## 5.1.2 Resuspension Effects of Dredging

### Master Comment 5.3

Commenters suggested that dredging will likely result in the greatest short-term, in-river contaminant release. They cite the Deposit N project as having caused resuspension and redistribution of sediment that can be expected during implementation of the Proposed Plan. Commenters also suggested that certain areas of OU 4 are very effective sediment traps and that restricting dredging to routine navigational dredging will achieve RAOs 4 and 5.

### *Response*

WDNR and EPA acknowledge that there will be some sediment resuspension during remediation of the Lower Fox River. However, even a very high-end estimate of loss is the 2.2 percent estimate from the SMU 56/57 project (USGS, 2000), which the commenters failed to acknowledge. Applying the loss rates from SMU 56/57, which removed the most highly contaminated sediments in the River, to the entire Lower Fox River proposed remediation (~29,500 kg) would equate to a loss of less than 650 kg of PCBs.

On the other hand, the FRG offered that the annual PCB export from July 2000 to July 2001 was up to 106 kg (Exhibit 8, Volume 4) and that the rate of decline approximates a half-life of 9 years (Volume 1, p. 51). If one accepts this rate of decline at face value and applies it to the next 20 years, almost 40 percent less PCB would be resuspended and transported to Green Bay during active remediation (650 kg) than doing nothing (1,140 kg).

WDNR and EPA do not agree with the conclusion of the commenters that navigational dredging is more effective at achieving RAOs 4 and 5 than active remediation. This is based, in part, on the following considerations:

1) The comment offered by the FRG that: "…clamshell may spill 20-30 percent of sediment during hoisting (NAS Report, p. 199–201)" (Volume 1, p. 227);

2) The commenters failed to recognize that navigational dredging in the Lower Fox River is currently performed mechanically using clamshells; and

3) The documented losses from the SMU 56/57 project (discussed above) which used hydraulic dredging.

### Master Comment 5.4

Commenters suggest that the FS failed to account for remobilization of PCBs during dredging in its analysis of the protectiveness or effectiveness of dredging. The commenters suggested that WDNR provide a mass-based, dredging-induced PCB loading criteria, or provide a quantitative assessment of the actual impacts posed by these releases or expected releases during the long-term dredging project.

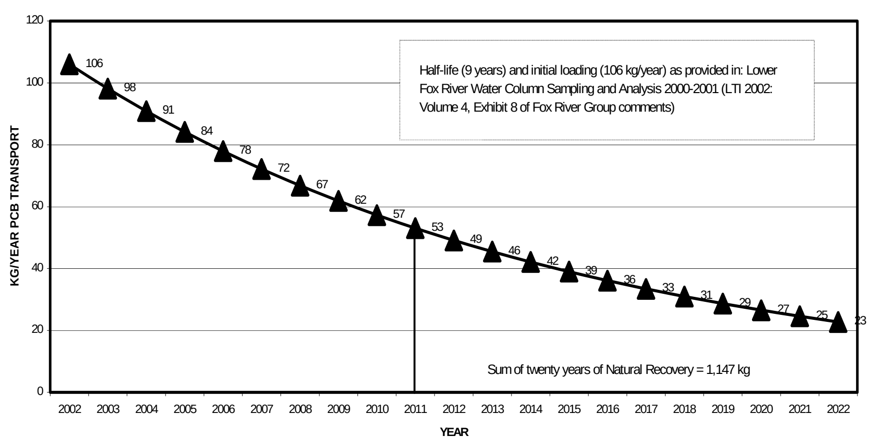
### *Response*

WDNR and EPA believe that appropriate loading criteria from losses due to dredging should be equal to those determined during the dredging project at

SMU 56/57 (USGS, 2000). Based on these results, where the commenter acknowledged that this set of data represents the most comprehensive data set available, the PCB loss approximated 2.2 percent of the mass removed. Applying the loss rates from this project that removed the most highly contaminated sediment in the entire Lower Fox River to the proposed remediation would equate to a total loss of 644 kg of PCBs. The commenter supplied a PCB decline rate, which the Agencies believe is incorrect. However, even applying this rate of decline at face value, over the next 20 years, almost 40 percent less PCBs mass would be transported to Green Bay during active remediation (650 kg) than by the no action alternative (1,140 kg). Similarly, the target removal of 1,700 kg of PCBs from Little Lake Butte des Morts would potentially release less than 40 kg of PCBs, roughly only twice as much as one responsible party suggested is contributed annually to the loading leaving Little Lake Butte des Morts.

Relative to PCB concentrations, data collected during high-flow events or ship movements within the River have clearly shown that these actions can result in concentrations equal to concentrations found during dredging.

## Figure 4 Water Column PCB Half-Life




### Reference

USGS, 2000. *A Mass-Balance Approach for Assessing PCB Movement during Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. United States Geological Survey Water-Resources Investigations Report 00-4245. United States Geological Survey. December.

## Master Comment 5.5

Commenters offered that methods for assessing the fate and impact of PCB releases from dredging are illustrated in the recent comprehensive assessment of the issue and submitted with these comments. In addition, the commenters encourage the inclusion of dredging losses into the water quality modeling.

## *Response*

Methods illustrated in this document relate only to the Hudson River. WDNR and EPA do agree with the commenter's statement that: "Variations in site characteristics, the components of the remedy and their relevance to the lower Fox River, the method of sediment removal, the method and effectiveness of environmental controls, volume of sediment removed, and multiple contaminants of concern make direct comparisons between "successes" at other sites to the proposed project for the Lower Fox River nearly impossible."

As for the incorporation of dredging releases into the water quality modeling, WDNR and EPA see little value in including another highly variable factor into models. Any differences between model results with or without the 2.2 percent dredging losses observed at SMU 56/57 are well within the uncertainty of the models, given the acceptable threshold for model performance developed in cooperation with the FRG (*Model Evaluation Workgroup Technical Memorandum 1: Model Evaluation Metrics*). The acceptable level of performance defined in Technical Memorandum 1 is ±30 percent of observed concentrations.

## Master Comment 5.6

The commenter expressed a desire that sediment handling processes should minimize volatilization of PCBs and the Agencies should maximize the use of innovative, safe, and permanent treatment technologies.

## *Response*

Regarding the commenter's position on volatilization of PCBs, the FRG undertook an extensive air monitoring program at the SMU 56/57 dredging project. Ambient air PCB concentrations recorded on and near the site were less than 80 percent of the conservative lifetime risk level while off-site risks never exceeded 4 percent. Whereas PCB volatilization during remediation of the most highly contaminated sediment in the Lower Fox River did not exceed unacceptable levels, WDNR and EPA do not consider volatilization to be a significant issue. However, losses from all pathways will be further evaluated and minimization strategies incorporated into the final remedial design.

Regarding the preference for permanent treatment technologies, comment noted.

## 5.1.3 Post-Dredging Residual Sediment Concentrations

### Master Comment 5.7

Commenters stated that evidence from previous environmental dredging projects indicates that achieving an average SWAC sediment PCB concentration of less than 1 ppm is not attainable. They cite environmental dredging projects that they contend show post-remedial concentrations ranging from 2 to 16 ppm. They maintain that the record of environmental dredging at achieving remedial goals has been poor, and that no large-scale dredging project has ever been able to leave behind an average SWAC as low as 1 ppm.

### *Response*

WDNR and EPA disagree with this statement and believe that with a carefully designed and executed remedial action, the overall goal of reducing the concentration of PCBs to levels below 1 ppm is achievable.

As documented in Appendix B of the FS, the *Sediment Technologies Memorandum*, the environmental dredging projects listed by the commenters as evidence of dredging ineffectiveness were in fact very effective if examined in light of the project goals. As stated in Section 5.1.1 above, imposing numeric “risk reduction” criteria on projects that were designed to remove mass is misleading. In the opinion of WDNR and EPA, these projects were successful and the lessons learned from those cited projects will be carried forward into the remedial design.

The *Sediment Technologies Memorandum* project review highlighted the fact that the success of a removal operation and residual contamination depends upon a number of factors. Several of the important factors that will be germane to the final remedial design on the Lower Fox River include:

- An experienced dredging design consultant;
- Early identification of required approvals/permits, and ability to comply with them;
- Adequate baseline monitoring to verify achievement;
- Verification sampling before demobilization from the Site;
- Long-term monitoring in place or considered;
- Physical constraints anticipated;

- Adequate physical characterization of impacted sediments including design level informational studies;
- Contingency plan for evaluating exceedances during dredging;
- Selection of equipment compatible with Site conditions and the constraints of the project;
- Type and depth of materials that underlie the dredging horizon;
- Average level of contamination above the dredging horizon prior to dredging;
- Depth of sediment to be removed; and
- Ultimate cleanup goal of the project.

Where these elements have been incorporated into the remedial design, those projects have successfully met their goals of either mass removal and/or risk reduction.

Several of the remedial dredging projects described by the commenters and then listed in Table 6 of their response (FRG Volume 1, p. 223) involved sites where contaminated sediments were underlain by hard substrate. These are discussed in detail in the white paper prepared for the Hudson River Responsiveness Summary entitled *Post-Dredging PCB Residuals*, White Paper 312663. WDNR and EPA concur with the findings of that document. Further, the Agencies note that site-specific conditions prevented over-cutting of contaminated materials, a strategy that could have led to significantly lower PCB residuals. Comparable conditions are expected to be encountered in some areas targeted for active remediation by WDNR. Within OUs 1, 3, and 4 of the Lower Fox River, the targeted fine-grained sediments are generally underlain by: (1) older fine-grained sediments, thus permitting an over-cut to be taken with the goal of leaving relatively clean sediments exposed; or (2) hard clay substrate that could be over-cut.

Based on WDNR's review of the sediment residuals from case study projects, it is apparent that sites with higher initial PCB concentrations yielded higher PCB residuals after dredging than did sites with relatively lower PCB levels. In this regard, the Lower Fox River is at the lower end of the PCB contamination spectrum (in terms of sediment PCB concentration). For the Lower Fox River, a targeted residual of 1 ppm PCBs represents a reduction of 96 to 98 percent from pre-dredge sediment concentrations.

## Master Comment 5.8

Some commenters argued that dredging cannot reliably and consistently achieve the 1 ppm cleanup objective that WDNR and EPA have set for the Lower Fox River. They argue that the results of the demonstration projects on the Lower Fox River itself (Deposit N and SMU 56/57) demonstrated that none of these projects achieved a site-wide post-dredging average surface sediment concentration as low as 1 ppm.

## *Response*

WDNR and EPA do not agree that the results of the demonstration projects point to an inability to achieve the environmental benefits outlined in the Proposed Plan. The demonstration projects had different remedial goals and successfully achieved those goals. The aims, goals, and the outcome of the demonstration projects, germane to answering this comment, are discussed below.

### Deposit N Demonstration Project

The Deposit N demonstration project is discussed at length in the *Sediment Technologies Memorandum*, with complete reports available at WDNR's website: http://www.dnr.state.wi.us/org/water/wm/lowerfox/demoproj.html.

At Deposit N, the target goal of the dredging project was to achieve mass removal of PCB-contaminated sediment down to the design elevation and to assess the protectiveness of environmental dredging in removing PCB contamination. The project objective was to use the information gained to assess appropriate remedial technologies, effectiveness, and implementation of the selected technology and costs for a large-scale remedy of the Lower Fox River. Residual surface sediment concentration was not a performance-based criteria endpoint for the project. The commenter's contention that pre- and post-sediment sampling was conducted to document the effectiveness of dredging in "reducing the availability of PCBs for uptake to the food web" (FRG Volume 1, p. 218) is factually incorrect. Dredging occurred to a design depth of 6 inches above bedrock to achieve mass removal. A total of 106 pounds was successfully removed from Deposit N (Foth and Van Dyke, 2000).

WDNR and EPA also believe that the conclusion offered by the independent review conducted by the Fox River Remediation Advisory Team (FRRAT) (FRRAT, 1999) for Deposit N supports the Proposed Plan remedial design and cleanup goals. The FRRAT report notes that sediments from the deposit, representing 96 percent of the PCBs and 87 percent of the mercury were removed from the portion dredged (the western lobe). The concentrations of PCBs and mercury in treated waters discharged back to the Lower Fox River were less than 0.01 percent of the concentrations in the sediment slurry transported to the shoreside treatment site. Based on the results of Phase I activities, the advisory team reached the following conclusions regarding the effectiveness of dredging at Deposit N:

- Environmental dredging is an effective mechanism for removal of contaminated sediments from Deposit N in the Lower Fox River;
- A mass balance approach is the most scientifically defensible measure for assessing the effectiveness of a dredging operation;
- Shoreside processing was an effective means of concentrating and permanently removing contaminated sediments from the River;
- Dredging on the Lower Fox River should be conducted during a period when monitoring is sufficient to determine losses from the activity;
- Common techniques such as measurement of TSS and turbidity do not adequately describe riverine transport of PCBs;
- Prior to dredging, Deposit N represented an active source of PCBs to the Lower Fox River and was not "naturally" capping with clean sediments;
- The demonstration project at Deposit N provided information important for future shoreside processing design;
- The demonstration project at Deposit N provided information important for water column sampling designs; and
- The mass balance framework is a feasible and useful approach for future dredging activities.

### SMU 56/57

The SMU 56/57 demonstration project is discussed in the *Sediment Technologies Memorandum*, with complete reports available at WDNR's website: http://www.dnr.state.wi.us/org/water/wm/lowerfox/demoproj.html. This includes reports on the removal and disposal portions of the project, as well as studies conducted by the USGS that evaluate PCB resuspension issues during the project (see also Section 5.1.2), as well as a report on the monitoring of PCB volatilization to air during the removal projects (see also Sections 5.1.4 and 8.4.1 of this RS).

The objectives for the SMU 56/57 project called for the removal of a specific volume of contaminated sediment from an area established in the original 1999 pilot project. The objectives of the work in 2000 called for the area to be dredged to a specific elevation. The remaining sediment was then sampled. Areas with PCB concentrations less than 1 ppm were considered to be completed and needed no further work. Areas with PCB concentrations between 1 and 10 ppm were to be covered with at least a 6-inch layer of sand. If confirmation sampling showed levels above 10 ppm, the dredging was to continue until the PCB concentration in the surface sediment was below 10 ppm.

Pre-removal, samples collected at the site showed concentrations of up to 710 ppm within SMU 56/57. After the two seasons of operations (under different construction firms), all the cleanup objectives were met for this project. Confirmation samples taken from the site ranged from "non-detect" to 9.5 ppm. Eleven out of 28 samples (about 40 percent) were less than 1 ppm and 24 of the 28 samples (86 percent) were below 4 ppm. Since this project was classified as an emergency response action, the cleanup objectives were specific for this project, and are not indicative of what the objectives would be for a cleanup of the entire River. Over the 2 years the project was operational, 2,111 pounds of PCBs were removed from the River.

### References

Foth and Van Dyke, 2000. *Summary Report Fox River Deposit N*. Prepared for the Wisconsin Department of Administration, Wisconsin Department of Natural Resources by Foth and Van Dyke, Green Bay, Wisconsin. April.

FRRAT, 1999. *Evaluation of the Effectiveness of Remediation Dredging: The Fox River Deposit N Demonstration Project November 1998–January 1999*. Fox River Remediation Advisory Team, Madison, Wisconsin. Website: http://www.dnr.state.wi.us/org/water/wm/lowerfox/sediment/depositnevalu.htm.

## Master Comment 5.9

Commenters listed the Manistique River and Harbor (Manistique, Michigan) removal action conducted on behalf of the EPA as another example of the inability of dredging to reduce surface sediment concentrations, and that the RAL of 1 ppm for the Lower Fox River is unachievable. They further contend that dredging increased PCB surficial sediment concentrations and bioavailability at that site. Furthermore, they maintain that the average surface sediment PCB concentrations in areas that were not dredged (in Manistique Harbor) have decreased since 1993. In areas that were dredged, exposing underlying concentrations, average surface sediment PCB levels have increased.

## *Response*

Manistique Harbor is an example of a site where on-site conditions have presented considerable challenges to the removal operation. As discussed in the *Sediment Technologies Memorandum*, the many challenges at this project have contributed to many of the "lessons learned" that are being now applied for planning at other projects, including the Hudson River as well as the Lower Fox River. Implementation of the dredging project was made more difficult by an incomplete site characterization prior to starting dredging activities. Design components were constructed from sediment cores that supposedly hit refusal when the cores actually hit buried wood and debris, and not bedrock. The dredging equipment was selected based on this premise. The difficulty of dredging wood, sawdust, rock, and gravel was not fully considered when estimating the cleanup effort. Due to site conditions, most dredged areas were not initially cleaned up to meet target objectives and subsequently needed to be re-dredged, sometimes multiple times. Thus 100 percent removal of contaminated sediments was not possible by an over-dredging technique, and areas had to be re-dredged multiple times over multiple years.

The "lessons learned" from the Manistique project as well as results on the Deposit N and SMU 56/57 demonstration projects have been considered and incorporated in the Lower Fox River and Green Bay Proposed Plan and ROD. These "lessons" inform us that, among other concerns, shallow bedrock overlain with contaminated sediments and debris presents challenges that require careful planning and design, along with experienced contractors. Without these factors considered, it may be very difficult to achieve risk reduction goals. While shallow bedrock underlying contaminated sediments is not a concern for OU 1, it is a concern in OU 2. Therefore, implementability and effectiveness are considerations incorporated into the decision to not dredge in OU 2, instead relying on MNR as the remedial alternative for that OU.

## Master Comment 5.10

Commenters stated that the residual PCB concentrations after dredging would exceed the RAL of 1 ppm. They argue that the Proposed Plan projects that removal would result in a post-remediation SWAC of 0.19, 0.26, and 0.16 ppm in OUs 1, 3, and 4, respectively, and that the Proposed Plan assumes success in reaching a low-concentration "bottom," along with no recontamination problems from sediment resuspension during dredging.

## *Response*

WDNR and EPA believe that the residual concentrations assumed in the Feasibility Study for dredge areas are a reasonable and conservative assumption. The *Sediment Technologies Memorandum* (Appendix B of the

FS) showed an average 97 percent concentration reduction for five dredging projects. Additionally, the Hudson River Responsiveness Summary White Paper (*Post-Dredging PCB Residuals* [ID 312663]) showed dredging residual concentrations 96 to 98 percent for nine projects evaluated. Additionally, the Lower Fox River SMU 56/57 dredging project had a 96 percent concentration reduction; pre-dredging PCB concentrations were greater than 50 ppm and post-dredging concentrations were 2 ppm. The Lower Fox River dredging project would use similar equipment and techniques as these projects for comparable site conditions. Thus, WDNR and EPA believe that an estimate for residual PCB concentrations of less than 1 ppm is reasonable and, if anything, conservative.

## Master Comment 5.11

Commenters stated that the Consent Order for SMU 56/57 required that the residual surface sediment PCB concentration after dredging not exceed 10 ppm, and that a sand cap at least 6 inches thick be placed over areas where the residual surface sediment PCB concentration was greater than 1 ppm. They contend that since a sand cover was placed over the entire dredge area at SMU 56/57, although some of the dredged areas did not require a cap by the Consent Order, that this is another indication that post-dredge surface sediment concentrations will be greater than 1 ppm.

## *Response*

WDNR and EPA strongly disagree with this comment, and submit that the commenters have misconstrued the intent of the placement of a sand cap over the entire area. As discussed in Master Comment 5.8, it is important to understand that pre-removal, samples collected at the site showed concentrations of up to 710 ppm at SMU 56/57, and that post-remedy confirmation samples taken from the site ranged from “non-detect” to 9.5 ppm. Eleven out of 28 samples (about 40 percent) were less than 1 ppm and 24 of the 28 samples (86 percent) were below 4 ppm.

Concerning the placement of the sand cap, WDNR and EPA gave the Fort James Corporation (now Georgia Pacific Corporation) a release from all future liabilities at SMU 56/57 where removal achieved final concentrations of less than 1 ppm, or where a sand cap was placed over PCB concentrations less than 10 ppm. Given the results of the post-dredging confirmation sampling, a sand cap over the entire area was not required. However, Fort James Corporation voluntarily chose to cover the entire dredged area with sand to delineate the area for which they obtained a release from WDNR and EPA for future possible remedial actions at that site.

## Master Comment 5.12

Commenters stated the impacts of sediment removal must be correctly and fully assessed in the FS and that potential impacts of sediment plumes from dredging are well known. These impacts from the dredging process can result in the exposure of high PCB concentrations buried in the sediments directly to the water column and the dispersal of PCBs to other areas through resuspension.

## *Response*

WDNR and EPA believe that the concerns raised by the commenter will be managed in a correctly designed and implemented remedial alternative. As documented in the response to Master Comment 5.10 above, the Agencies believe that the SWAC can be achieved for each OU, even though there will be instances where individual sample location concentrations will exceed the RAL.

The Agencies also believe it is important that the issue of residual risk be placed into context, and balanced with impacts associated with ongoing PCB releases to the water column and impacts to the aquatic biota. While much is made of the residual sediment concentrations, the fact remains that all parties evaluating the food web within the Lower Fox River agree that uptake, and hence exposure, comes from resuspended PCBs, not bedded sediments. The Lower Fox River is a pelagic-based food chain (WDNR, 2001; Exponent, 1999), and the uptake to fish, and subsequently humans and piscivorous wildlife, comes from the resuspended PCBs, not the bedded sediment PCBs. The Agencies note that the commenters point to the decrease of sediment concentrations at SMU 56/57 from as high as 710 ppm to an average of 2.2 ppm as a “failure” of dredging to achieve risk reduction goals. What is not discussed in the assessment is that the removal of over 2,000 pounds of PCBs from the River in one small area equates to over 10 years of export and exposure of PCBs into Green Bay. The net residual sediment concentrations contribute negligible quantities (and hence risks) to biota from either the WDNR or FRG food web models.

### References

Exponent, 1999. *Model Evaluation Workgroup Technical Memorandum 7a: Analysis of Bioaccumulation in the Fox River*. Prepared for the Fox River Model Evaluation Workgroup by Exponent Bellevue, Washington. February.

WDNR, 2001. *Technical Memorandum 7c: Recommended Approach for a Food Web/Bioaccumulation Assessment of the Lower Fox River/Green Bay Ecosystem*. Wisconsin Department of Natural Resources, Madison, Wisconsin. January.

## Master Comment 5.13

Commenters cite a 1991 USACE document stating that "no existing dredge type is capable of dredging a thin surficial layer of contaminated material without leaving behind a portion of that layer and/or mixing a portion of the surficial layer with underlying clean sediment." This quote is used to support their supposition that dredging requires considerable "over-dredging" to remove target deposits (laterally and vertically), and that residual concentrations below 1 ppm cannot be achieved.

## *Response*

The commenter cites a 1991 USACE document, without acknowledging that technology has advanced, and that several USACE, EPA, and industry documents have been released that document the numerous technological advancements in removal options. This includes the following documents cited in the FS:

- *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Remediation Guidance Document* (EPA, 1994);
- *Innovations in Dredging Technology: Equipment, Operations, and Management* (McLellan and Hopman, 2000);
- *Dredging, Remediation and Containment of Contaminated Sediments* (Demars et al., 1995); and
- *Advances in Dredging Contaminated Sediment: New Technologies and Experience Relevant to the Hudson River PCBs Site* (Cleland, 1997).

Case studies described in the *Sediment Technologies Memorandum* (Appendix B of the FS) have typically shown that 6 inches of vertical "over-dredge," when feasible, have met post-verification surface sediment concentration goals after remediation. Newer and better equipment improves on the ability to remove thinner sediment layers with less fallback. For example, in the more recent USACE-sponsored demonstration action in New Bedford Harbor, the mechanical bucket recently developed by Bean Environmental Dredging, Ltd. was able to extract 90 percent of the mass at the test site in a single pass. Surface sediment concentrations (pre-removal) were 2,600 ppm, whereas after a single pass they were reduced to 29 ppm.

The objective of vertical over-dredging is to ensure that the bulk of impacted sediments have been removed with minimal residuals left in place. The objective of lateral over-dredge beyond the dredge footprint is to ensure slope stability during removal operations and will be considered during the design phase. In areas where over-dredging is not feasible, post-verification metrics other than discrete surface sediment concentrations (SWACs) should be considered in order to quantitatively determine potential risk reduction benefits. Natural attenuation is governed by "over-dredging" but by different processes such as sediment burial, dechlorination, and biodegradation.

**References**

Cleland, J., 1997. *Advances in Dredging Contaminated Sediment: New Technologies and Experience Relevant to the Hudson River PCBs Site*. Scenic Hudson, Inc., Poughkeepsie, New York.

EPA, 1994a. *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Remediation Guidance Document*. EPA 905-B94-002. United States Environmental Protection Agency, Great Lakes National Program Office.

Demars, K. R., G. N. Richardson, R. Yong, and R. Chaney, 1995. *Dredging, Remediation and Containment of Contaminated Sediments*. American Society of Testing Materials Publication STP 1293.

McLellan and Hopman, 2000. *Innovations in Dredging Technology: Equipment, Operations, and Management*. ERDC-TR-DOER-5. Prepared for the United States Army Corps of Engineers, Dredging Operations and Environmental Research Program. April 5.

# 5.2 *In-Situ* Sediment Caps

## Master Comment 5.14

Some commenters noted that the draft FS and Proposed Plan evaluated only a single cap design. They indicated that the single design was not appropriate, and suggested that the FS should have designed the caps (e.g., design thickness, materials, armoring) following procedures defined in the EPA and USACE guidance documents (Palermo et al., 1998a, 1998b).

## *Response*

*In-situ* capping (ISC) was identified within the Draft FS for the Lower Fox River and Green Bay as an appropriate and applicable remedy for consideration within the Lower Fox River and Green Bay. Illustrative designs for ISCs were described in the FS and incorporated into alternatives, which were incorporated into the FS and evaluated for each reach OU of the River based upon site-specific physical considerations. ISCs were then further evaluated using CERCLA criteria related to short- and long-term effectiveness, implementability, reduction in toxicity, mobility, volume through treatment, and cost.

WDNR and EPA agree that for final design, any ISC should be designed for the specific site and location for which it is intended. The Agencies do disagree, however, that it is necessary or needed for the purpose of a feasibility study. As articulated in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* (Palermo et al., 2002), the necessary minimal engineering design evaluations include the following:

- Modeling to assess consolidation;
- The potential for advective and diffusive flux from either consolidation or from groundwater intrusion;
- An evaluation of local capping material and iterative design testing to insure that the cap design is effective at chemical isolation;
- An evaluation of the 100-year shear-stress forces at the sediment/water interface to effectively evaluate physical stability and design and armoring layer as necessary; and
- An evaluation of whether the placement of the cap would result in an alteration to the flood channel, as required by Wisconsin state law. These are only some of the technical considerations, and do not include the regulatory, public acceptance, land use, and long-term fiduciary responsibility issues.

In responding to comments on the Draft FS and Proposed Plan, WDNR and EPA requested that Dr. Michael Palermo review the FS design and alternative capping proposals that were submitted as part of the public comment. *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* provides a detailed description of the technical, engineering, construction, monitoring, and regulatory/institutional requirements for capping on the Lower Fox River. That white paper, along with Dr. Palermo's comments to the FS and on the submitted capping alternatives (*White Paper No. 6A – Comments on the API Panel Report*) form the basis of the responses below.

The FS evaluated which minimum physical designs had been successful at other capping sites throughout the world, relative to conditions on the Lower Fox River to develop an adequate representative cap design for the purposes of the FS. These projects were provided in Appendix D to the FS, and are updated in Table 3 of *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. Professional judgment was exercised by the staff working on the FS, who have been involved in the design, construction, and/or monitoring of several capping sites. Given that there have been no demonstrated long-term monitoring on effective caps in a riverine environment, the representative design option required some conservatism. In order to effectively evaluate a capping alternative in a riverine environment, an engineering decision was made to utilize a design that had a demonstrated environmental track record.

Successfully applied caps with track records were recorded in Appendix B of the FS. That table has been updated in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. As documented in Section 7.1 of the FS, a 20-inch sand cap overlain by 12 inches of graded armor stone was selected as the representative process option for all locations. The FS went on to note, however, that several thinner or thicker cap designs may be applicable during final design and implementation. As a representative option, the Agencies consider the design to be adequate.

### References

Palermo, M. R., T. Thompson, and F. Swed, 2002. *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. In: *Responsiveness Summary – Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study*. Prepared for Wisconsin Department of Natural Resources and the United States Environmental Protection Agency by United States Army Corps of Engineers. December.

Palermo, M. R., J. E. Clausner, M. P. Rollings, G. L. Williams, T. E. Myers, T. J. Fredette, and R. E. Randall, 1998a. *Guidance for Subaqueous Dredged Material Capping. Technical Report*. DOER-1. United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. Website: http://www.wes.army.mil/el/dots/doer/pdf/doer-1.pdf.

Palermo, M. R., J. Miller, S. Maynord, and D. Reible, 1998b. *Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In-Situ Subaqueous Capping of Contaminated Sediments*. EPA 905/B-96/004. Prepared for the Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, Illinois. Website: http://www.epa.gov/glnpo/sediment/iscmain.

## Master Comment 5.15

Several commenters argued that an engineered cap, which was less extensive than the single option considered in the FS, should have been evaluated. They further stated that the Draft FS rules out thin-layer capping as an option on the grounds that River velocities are too high, despite Lower Fox River stream velocity data presented in the Draft FS itself showing that even 100-year flows in OUs 1 and 3 are within the range of USACE guidance for thin layer capping.

### *Response*

There appears to be some confusion of the concept and use of the term “thin-layer” cap as used by sediment capping engineers, and what the commenters are suggesting here. As discussed in the FS, a thin-layer capping involves the placement of a thin (1- to 3-inch) layer of clean sediments that is subsequently mixed with the underlying contaminated sediments to achieve acceptable chemical of concern (COC) concentrations and/or enhance the natural attenuation process. Mixing occurs naturally as a result of benthic organism activity (bioturbation). This approach is best suited to situations involving contaminants that naturally attenuate over time, or where contaminant concentrations are sufficiently low that “dilution” is the preferred alternative. Examples of where this has been used include the West Eagle Harbor OU in Washington, and the Ward Cove, Alaska Superfund Site (see *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* for a discussion). Thin-layer capping, in this sense, has not been considered an acceptable alternative for the Lower Fox River. The FS does discuss thin-layer capping.

As discussed in the response to Master Comment 5.14, the cap design thickness used in each area will be a site-specific engineering determination made during the remedial design phase.

### Master Comment 5.16

Commenters stated the Draft FS and Proposed Plan ignore information showing that capping is a feasible approach for many areas of the River and that the FS only considered capping in River areas with the slowest currents. This is contracted by the Appleton Paper, Inc. Panel (the “API Panel”) conclusion that “a cap can be designed to be stable in almost any flow regime.”

### *Response*

This statement is not accurate. The FS considered capping a feasible alternative for all OUs on the River. As discussed in the response to Master Comment 5.14, proponents of capping cannot point to a single, successful capping alternative with a long-term environmental track record in a riverine environment. As such, the representative process design in the FS was conservatively based upon successful caps constructed elsewhere. Despite the commenter’s critique concerning current limitations, the FS capping alternatives for OUs 1 and 3 cover greater areas than those proposed by the API Panel (see FS Figures 7-17 and 7-30 relative to API Panel Figures 7 and 8). This is not true for OU 4, where both WDNR and EPA believe that the capping would be subject to greater erosional forces. In all respects, the capping alternatives presented in the FS are more conservative by design than those offered by the API Panel. Specific comments to the API Panel design are addressed in Section 5.5.

## Master Comment 5.17

Some commenters took issues with the cost basis proposed for the capping alternative in the FS. They maintained that capping costs were too high, and claimed that the FS determined that capping was not a feasible option.

## *Response*

It is important to distinguish that capping was a remedy component within the FS that included dredging and natural attenuation (depending upon the action level evaluated). That capping would be a sole remedy of any reach is likely not to be practicable, given the physical, regulatory, and institutional constraints (Palermo, 2002). Within the aerial footprint defined by the remedial action level, capping areas were identified to the maximum extent practicable, based upon the physical constraints (e.g., navigational channel, TSCA materials, depth, etc.). Within the remedial action level footprint, those areas for which a cap was not feasible were then included in a removal action. Areas outside the footprint were considered to be naturally attenuating.

It is not clear what element of capping the commenters are criticizing. The components of the capping remedy are based upon availability of local materials, and are derived from the FS staff's direct experience with engineering and constructing caps. The removal and disposal elements of the alternative assume disposal at a local commercial landfill. The costs expressed in the Final FS have been checked and modified as necessary to reflect landfill and transportation costs. In addition, the capping construction and monitoring components in the FS are consistent with those identified for other projects in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*.

### Reference

Palermo, M. R., 2000. *White Paper No. 6A – Comments on the API Panel Report*. Prepared for Wisconsin Department of Natural Resources by Michael R. Palermo, Ph.D. December.

## Master Comment 5.18

One commenter noted that an important consideration for any cap design is the potential for long-term diffusive and/or advective migration of dissolved PCBs into and through the capping material. The commenter further stated that the FS is unclear whether the potential for direct receptor contact with sediment-bound contaminants appears to have been ultimately considered when choosing sand as the principal cap material. It is suggested that the potential for transfer of dissolved PCBs (the commenter is referring to a uniquely bioturbation-driven mechanism for transfer of impacted pore water) should be considered and perhaps the cap augmented with some type of clay or other commercial product that might preclude advection and/or bioturbation

## *Response*

Both bioturbation and the potential for advective and/or diffusive flux were considered when evaluating the representative cap design. As stated in the response to Master Comment 5.14, the representative design thickness was selected based upon successful long-term isolation of contaminants at other sites. As documented in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*, a final engineered cap will need to have to consider availability of local materials, the potential for bioturbation of the cap, stability to erosion by hydrologic factors, advective and diffusive flux, as well as operational and institutional considerations. As for the issue of bioturbation, *White Paper No. 6A – Comments on the API Panel Report* notes that given the benthic infauna in the River, bioturbation will likely be limited to only a few millimeters.

## Master Comment 5.19

Some commenters felt that the technical restrictions placed upon cap locations within the FS were "arbitrary and unjustified." These issues included water depths, limits to ice scour, navigation channels, flow conditions, etc. The commenters felt that these restrictions "eliminated" the use of capping on the Lower Fox River.

## *Response*

An ISC must meet two basic conditions in order to be an effective remedial alternative: (1) it must be capable of isolating contaminants in perpetuity, and (2) it must be internally/externally stable against erosion. The physical restrictions identified within the FS were conservatively selected in order to ensure that any proposed alternative met these two basic needs. They are neither arbitrary nor unjustified. *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* provides a more detailed evaluation of these physical conditions, along with recommendations for their applications.

With regards to identification of capping areas within the River, large potential areas were identified in the FS as potentially suitable for capping. When compared at the same RAL (0.5 ppm), the FS capping alternatives for OUs 1 and 3 cover the same areas and more than those proposed by the API Panel (see FS Figures 7-17 and 7-30 relative to API Panel Figures 7 and 8). This is not true for OU 4, where both WDNR and EPA believe that the capping would be subject to greater erosional forces. Thus, while the design may be considered conservative, the application areas are essentially the same as those offered by the API Panel in the two southern OUs. Specific comments to the API Panel design are addressed in Section 5.5.

## Master Comment 5.20

Some commenters argued that the potential risk of localized cap failure can be minimized with proper cap design, installation, monitoring, maintenance, and repair. They further argued that there should be no restrictions to capping sediments with PCBs exceeding the TSCA criterion of 50 ppm.

### *Response*

WDNR and EPA agree that a properly designed, constructed, and monitored cap can be an effective remedial alternative. Furthermore, the need for long-term operations and maintenance is agreed to by all parties. What is less clear are the fiduciary mechanisms necessary to ensure that the long-term operation and maintenance costs are fully covered. These and other institutional and regulatory requirements are discussed in more detail in the *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*.

The ability of an ISC to meet the requirements of TSCA has not been fully established. TSCA-level sediments are present only in limited areas of OUs 1, 3, and 4. Based on these considerations, the *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* states that no capping of TSCA-level sediments should be considered.

## Master Comment 5.21

Commenters stated that land impacts regarding capping need to be included so that these impacts can be compared to the land impacts of dredging.

### *Response*

Land use impacts are discussed in the FS and in ISC *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. In general, impacts from staging areas for capping will be the same as for those of dredging. Land use impacts related to increased mining of quarry material for capping alternatives is beyond the scope of this FS.

## Master Comment 5.22

Commenters noted that there is an inconsistency in the FS in that the FS requires 6 feet clearance on top of a 32-inch cap after previously stating that 3 feet is all that is necessary.

### *Response*

This text inconsistency is noted and corrected in the Final FS. Capping areas in less than 6 feet of water were not considered for capping in order to ensure that water depths no less than 3 feet were created by cap installation. The only exception to this was in federal navigation channels. However, an important clarification in the *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* is that long-term Great Lakes level changes (from +5 to –1 feet) should be accounted for in designing for these restrictions for OU 4. Considering these restrictions, no cap should be constructed with a surface above -3 feet chart datum in OUs 1 and 3, and above -4 feet chart datum in OU 4. Removal may therefore be required prior to ISC placement in shallow-water areas.

### Master Comment 5.23

Commenters stated that the draft FS and Proposed Plan eliminate capping as a remedial option in any area of the River with a depth of less than 3 feet. However, the Draft FS errs by assuming that navigation takes place throughout the entire River, both in the navigation channel and out of the channel, in the middle of the River, and along the banks.

### *Response*

A federally authorized navigation channel system exists from the mouth of the River up to the Menasha Channel. Federal law prohibits construction within a federal navigation channel, unless congressional authorization is given. In OU 4, the USACE maintains an 18-foot-wide deep commercial channel in OU 4. For OUs 1 and 3, the USACE no longer maintains the authorized channel depth and there is no longer commercial traffic in these reaches. However, the WDNR has indicated that there will be future demand to maintain a 6-foot-deep channel in OUs 1 and 3 for recreational use. At a minimum, a Lake Bed Grant would be required to construct within the state-owned navigation channel.

### Master Comment 5.24

The Draft FS limited capping to areas of the River in which the average current speed is less than 0.15 feet per second (ft/s) and the maximum (100-year flood) current speed is no greater than 0.7 ft/s. The FS did not provide justification for this criterion.

### *Response*

The current criteria listed in the FS were derived using the bottom sheer-stress estimations as defined in *Technical Memorandum 5c, Evaluation of the Hydrodynamics in the Lower Fox River between Lake Winnebago and*

*De Pere, Wisconsin* (TM5c) (HydroQual, 2000). These velocities were tied directly to erosion/resuspension in the Lower Fox River.

### Reference

HydroQual, 2000. *Technical Memorandum 5C: Evaluation of the Hydrodynamics in the Lower Fox River Between Lake Winnebago and De Pere, Wisconsin*. Prepared for Limno-Tech, Inc. by HydroQual, Inc., Mahwah, New Jersey. December.

## Master Comment 5.25

Commenters noted the Proposed Plan cites as a “significant factor” in its selection of dredging the assertion that “the surface of any cap placed downstream of residual contamination may become recontaminated following placement, which can therefore reduce risk reduction by the cap.” This is wholly as dredged areas are subject to same risks of recontamination as capped areas.

## *Response*

The Agencies agree that downstream recontamination can occur from both cap placement over contaminated dredging and removal of contaminated sediment via dredging. The reason for indicating this in the Proposed Plan was to inform the public that a cap does not necessarily leave behind a sediment surface environment that is free of contamination as has been suggested. Recognizing that upstream resuspension and the potential for recontamination from either capping or dredging is another reason for addressing the upstream OUs first as is done in the ROD.

## Master Comment 5.26

One commenter argued that dredging does not improve on natural attenuation and that capping is the only generalized remedial alternative that can offer any environmental improvements.

## *Response*

WDNR and EPA do not agree with this statement. Both dredging and capping can provide similar levels of short-term protection when properly implemented. These two remedial options can be very different in terms of permanence and long-term protection. When properly designed and implemented, the Agencies believe either of these remedial options can provide significant improvement over natural attenuation in certain areas of the Lower Fox River.

### Master Comment 5.27

Some commenters expressed concern that capping in shallow-water areas may affect water depth, flood-carrying capacity, habitat function, and recreational activities, and may be affected by ice scour and wave action.

### *Response*

WDNR and EPA agree that capping in shallow areas would create concerns regarding stability, River use impacts, possible increases of risk, and achieving project RAOs. Operationally, no cap will be built that raises the mudline elevation to within 3 feet of the water surface. Baseline data, collected before remedial activities begin, will be compared to post-remedy flooding effects and habitat concerns. Thus, armoring was not evaluated, as it would be counterproductive to many of these monitoring data. If necessary, the remedy process may be subject to modification to meet the RAOs.

# 5.3 Monitored Natural Recovery

## 5.3.1 MNR as an Alternative

### Master Comment 5.28

Commenters noted that data presented in the Proposed Plan (p. 18) suggest that MNR will not work; below a concentration of 30 ppm PCB degradation does not occur and the majority of sediment concentrations in the River and the Bay are less than 30 ppm. Also, fish concentrations have not fallen for the last 12 years (p. 12, Figure 9) so how does this demonstrate that MNR will work?

### *Response*

WDNR and EPA stand by the decision to select MNR for OU 2. This decision is based on risk reduction and is discussed in Section 9.7 of the Proposed Plan. In summary, this section states that that OU 2 contains a relatively small amount of PCBs and contaminated sediments. Furthermore, of the 22 sediment deposits that are within OUs 2 and 4 contain 58 percent of the estimated PCB mass. Two deposits (N and O) have been remediated as part of the demonstration project and a second deposit (DD) is being targeted for potential remediation as part of the ROD.

Furthermore, the reference to 30 ppm PCBs on page 18 of the Proposed Plan refers to the lower level in which natural degradation of PCBs will occur. Degradation is only one of several components of natural recovery. Other natural recovery processes include burial as well as dispersion of material within the River. Concerning Figure 9 on page 12 of the Proposed Plan, while this does demonstrate a trend in fish tissue concentrations, it is specific to Little Lake Butte des Morts, not the River and Bay.

## Master Comment 5.29

A comment by the API Panel stated that natural recovery cannot serve as a feasible primary or singular remedy and that sedimentation is too slow to isolate high concentrations in a short time.

## *Response*

WDNR and EPA agree with the API Panel on this statement. Their decision to proceed with active remediation was based on risk reduction and time necessary to reduce or eliminate consumption advisories for fish. WDNR and EPA concur that the processes involved in natural recovery; degradation, dispersion, and burial, are not amenable to an effective and expeditious remediation of the Lower Fox River. Modeling of the River shows no action and natural recovery would result in a prolonged time period to reduce health risks when compared to active remediation.

## Master Comment 5.30

Commenters stated that the MNR component of the Proposed Plan relies too heavily on potentially ineffective fish consumption advisories and does not account for dam removal and/or maintenance.

## *Response*

WDNR and EPA believe that the criteria established concerning the time necessary for the reduction in PCB concentrations in fish tissue are reasonable. Furthermore, while not all consumption advisories will be able to be removed once the remediation is complete, WDNR and EPA do expect that as time passes, the advisories will be removed or reduced based on computer modeling. WDNR and the PRPs will also continue to monitor fish for tissue concentration reduction. Fish consumption advisories are only effective if fish consumers are aware of the advice and choose to follow that advice. WDNR, in cooperation with the Wisconsin Division of Health, will revise the fish consumption advisories for the Lower Fox River and Green Bay according to the Great Lakes Task Force Protocol and continue to provide that information using a variety of methods (e.g., publications, news releases, Internet sites). In addition, these Agencies plan to continue educational efforts such as posting advisories at boat landings and providing literature on advisories in multiple languages.

WDNR did an evaluation of the dams on the Lower Fox River. The dams on the River are all inspected on a regular basis, have to undergo re-licensing every 20 years by FERC, and there are no plans to remove any of the dams at this time. This inspection and licensing program should avoid any catastrophic dam failure. Should a decision be made to remove a dam or should it become necessary, the water behind the dam would be gradually lowered. This may result in resuspension of sediment.

## Master Comment 5.31

A commenter stated that natural attenuation and the alternative remedy are more protective than the Proposed Plan remedy and that, in fact, both natural attenuation and the alternative remedy are superior to the Proposed Plan remedy in terms of compliance with chemical-specific ARARs relating to water quality because they do not increase PCB water column concentrations, and location-specific ARARs.

## *Response*

The WDNR and EPA do not agree with this opinion. The analyses provided in the RI/FS, the BLRA, and the Proposed Plan all point to significant benefits for active remediation in OUs 1, 3, and 4. Even the expert panel hired by API indicated that they believed that active remediation is needed in the Lower Fox River. WDNR and EPA believe the recommended plan will result in reduction, in the long run, of water column concentrations. This was discussed in Table 9 of the Proposed Plan and in the FS.

## Master Comment 5.32

A commenter contended that natural recovery is occurring in Little Lake Butte des Morts, except in two hot spot areas – Deposit A and the southwestern portion of Deposit POG.

## *Response*

WDNR and EPA disagree with this statement. As stated in Master Comment 2.14, recent sampling completed in OU 1 showed that sediment concentrations are higher at both Deposit A and Deposit POG than have ever been previously measured. In addition, all samples collected in Deposit E showed that sediment PCBs still exceed the RAL of 1 ppm.

## Master Comment 5.33

Some commenters felt that natural attenuation would work better than the Proposed Plan's dredging remedy to protect the Lower Fox River's environment.

## *Response*

WDNR and EPA assessed numerous technologies for remediation of the Lower Fox River and Green Bay. This evaluation included no action, MNR, capping in combination with other technologies, dredging, and others. Following the evaluation of technologies, WDNR and EPA considered the effectiveness of the technologies at reducing risk at various action levels along with cost and implementability. Using the tools in the RI/FS and BLRA, WDNR and EPA's analysis demonstrates that natural recovery will have limited effectiveness to the area defined as OU 2. In the other OUs, there is significant benefit associated with active dredging of contaminated sediments to reduce surface concentrations. Evaluations completed by WDNR and EPA indicated that natural attenuation or natural recovery do not provide sufficient protection and are significantly less protective than the dredging remedy presented in the ROD. Evidence supporting this is:

- Bathymetric data showing continued re-exposure of contaminants;
- Many areas in OU 1 where the highest PCB concentrations are in the surficial sediments;
- Current risks are significantly above those considered acceptable by WDNR or EPA, and a weight-of-evidence approach informs the Agencies that any recovery would be relatively much longer than it would take for active removal (i.e., dredging);
- Dredging has been demonstrated to reduce contaminant concentrations and remove large amounts of contaminants;
- Contaminants that are removed will be disposed of in landfills with a design that has a well-demonstrated effectiveness for containment; and
- Dredging does not release significant quantities of contaminated sediments.

## Master Comment 5.34

Commenters stated that in none of the comparisons does the proposed dredging remedy offer any significant benefit over natural attenuation, and in all of the comparisons, the proposed remedy actually hinders the natural attenuation of Green Bay by causing more PCBs to be exported to Green Bay beyond what would be expected under natural attenuation. These comparisons demonstrate that the selection of the proposed remedy would be arbitrary and capricious.

## *Response*

WDNR and EPA disagree. Dredging offers several significant benefits over natural attenuation including a shortened time period in which PCB levels in the River will return to acceptable levels, and greater protection of fish and other aquatic life in the River by reducing their exposure to PCBs.

Natural processes would take more than 100 years for recovery, whereas a 1 ppm dredging remedy would remove fish consumption advisories in an estimated 20 years.

## Master Comment 5.35

Commenters stated that monitored natural attenuation was rejected as a river-wide remedy without support from any actual data that it will take too long and is not reliable or permanent because of the potential for scour generally, and/or due to catastrophic flood.

## *Response*

WDNR and EPA disagree with this statement, which incorrectly states natural attenuation is as effective as the remedy selected. Active remediation is more effective in protecting human health and the environment and it will more quickly reduce PCB transport to the Bay. This is pointed out in the comparative analysis of alternatives in Section 10 of the FS and is discussed in the ROD.

## Master Comment 5.36

Commenters stated that only in localized areas over relatively short periods of time would the proposed remedy provide any reduction in sediment SWAC compared to natural attenuation. In OU 4, the proposed remedy would actually retard the reduction in SWAC over time that natural attenuation provides.

## *Response*

WDNR and EPA disagree. Active remediation offers significant benefits over natural attenuation including a shortened time period in which PCB levels in the River will return to acceptable levels, and greater protection of fish and other aquatic life in the River by reducing their exposure to PCBs. Modeling projections suggest natural recovery would take more than 100 years for recovery, whereas a 1 ppm dredging remedy would remove fish consumption advisories in an estimated 20 years.

The Agencies recognize that immediately following the end of dredging operations, it is possible that patinas (thin residual layers) of more highly PCB-contaminated sediments may exist at the sediment-water interface. Such patinas were not explicitly included in the site-specific chemical transport and bioaccumulation models developed for the RI/FS. This model design factor was based on consideration of the ability of dredging technologies to achieve low residual PCB concentrations and the rapid rate at which conditions at the sediment-water interface are expected to change following dredging. As monitored following the first phase of the SMU 56/57 demonstration project in 1999, PCB concentrations in portions of the dredged area where post-dredging bed elevation meet the target elevations were approximately equal to PCB concentrations initially present at that sediment depth. This indicates that low residual PCB levels can be achieved by careful control of dredging to ensure sediments are removed with minimum disturbance to a depth required to achieve a desired residual. In addition, dredging alters the sediment transport regime of the dredged area. As a result, conditions near the sediment-water interface can change rapidly following dredging. Post-dredging monitoring of the SMU 56/57 site showed that rapid changes in the sediment-water interface occurred and that conditions a few months following dredging did not resemble conditions immediately following dredging. Based on these considerations, the effect of PCBs potentially present in post-dredge patina layers was considered negligible.

# 5.4 Remedy Selection

## Master Comment 5.37

One commenter stated that the ROD should specify hydraulic suction dredging as the default sediment removal technology because:

1) Hydraulic dredging produces the lowest levels of sediment resuspension;
2) Hydraulic dredging can be engineered to minimize volatilization;
3) Hydraulic dredging works faster than mechanical dredging; and
4) The ability to pipe sediment slurry as far as 10 miles can reduce equipment traffic on the River and eliminate heavy truck traffic on regional roadways.

## *Response*

Hydraulic dredging can be effectively used to control sediment resuspension, engineered to minimize volatilization, and connect to a sediment slurry pipeline to minimize equipment traffic. Recent technical advancements in mechanical dredges have led to greater precision in removing and limiting the release of excavated sediments, thereby minimizing sediment resuspension. Due to the unique characteristics presented by the River (bathymetry) and community (upland space for staging areas and processing areas), WDNR and EPA considered using both hydraulic and mechanical dredging technologies in the FS to effectively remove PCB-contaminated sediments from the Lower Fox River. These were both retained and either technology is allowed under “dredging” in the remedy described for OU 1. Both dredging technologies have been demonstrated to be effective for reduction of risks and for minimizing resuspension during dredging. However, it should be noted that appropriate design and competent operation are required to successfully implement either type of dredging.

## Master Comment 5.38

Some commenters suggested that natural attenuation will achieve a SWAC in the River of 1 ppm within the same period of time as the WDNR's and EPA's proposed removal plan. This is presented as an argument for no action by some commenters. They maintain that a 1 ppm SWAC will be achieved in OU 1 in 14 years, OU 3 in 5 years, and OU 4 in 15 years. They express the opinion that natural attenuation will achieve the same aims as the proposed remedy, and question the WDNR's and EPA's selection of an active remedy.

## *Response*

WDNR and EPA believe that the commenter misunderstands the risk reduction goals of the proposed remedy and confuses the RAL of 1 ppm with the term SWAC. Table 4 of the Proposed Plan shows that the active remediation will achieve SWACs of 0.19, 0.26, and 0.16 ppm, respectively, in the three OUs. The Alternative-specific Risk Assessment in the FS documents that, in fact, the sediment concentrations stated by the commenter are not likely to be met in 50 to 100 years, and thus the WDNR and EPA believe that active remediation is necessary.

## Master Comment 5.39

Commenters argued that the proposed remedy relies on data from OU 4 to support the proposed remedy for OU 1. They opine that the remedial decision is based in part upon the relationship between sediment and fish PCB concentrations that is derived from OU 4 data, and argue that there are important differences in the uptake of PCBs by fish in the two reaches. The commenters further state that transport modeling conditions developed in OU 4 are imposed upon modeling in OU 1.

## *Response*

The RI/FS and the accompanying BLRA considered each OU as a separate reach, each with its own set of COPCs, receptor species and food chain, human health exposure pathways, and remedial alternatives that were constructed with due consideration of local conditions. The commenter is in error to suggest that the remedy proposal for OU 1 is based upon conditions observed in OU 4.

Following the issuance of the Draft RI/FS in 1999, EPA's National Remedy Review Board recommended that the WDNR consider various levels of remediation for the Lower Fox River rather than selecting a single cleanup level based solely on the risk assessment. These RALs are explained in the FS and the Section 7.2 of the Proposed Plan. Section 9.6 of the Proposed Plan explains the basis for selecting the action level of 1 ppm for all three OUs. While the end result of the selection process was that the same action level was selected for all three OUs; the selection of the action level for each OU was independent of the other OUs.

Regarding the model representation of solids dynamic processes in wLFRM for Little Lake Butte des Morts, the results from the sediment transport model as documented in TM5d were used to parameterize the critical sediment resuspension events as shown in Table 3-7 in Appendix B of the FS. Results from TM2g were discussed and used qualitatively.

## Master Comment 5.40

A commenter stated that closed-loop PCB destruction technologies should be used for higher concentration sediments (greater than 50 ppm PCBs), such as the Eco-Logic process described in the attached document, *Available Non-combustion POPs Destruction Technology*. Burning, melting, or incineration technologies must not be used due to the likely formation of dioxins and furans and the high potential for release of co-contaminants (mercury and lead).

## *Response*

Data generated by the EPA Superfund Innovative Technology Evaluation program shows that vitrification (glass furnace technology [GFT]) does not generate dioxins and furans in the off gases from these technologies. Further, the WDNR and EPA do not agree with the commenter’s assertions that properly engineered and operated pollution control equipment does not reduce emissions of heavy metals to regulated levels.

## Master Comment 5.41

A commenter stated that the proposed remedy presentation was vague and difficult to comment on and cites the Proposed Plan’s reference to an unnamed landfill and public right-of-way to run a pipeline from the Lower Fox River to the unnamed landfill.

## *Response*

The level of detail provided in the RI/FS and supporting documents is consistent with Superfund guidance. The intent of providing this level of detail at this point is to determine whether the proposed remedial project for a site is feasible before developing the site-specific design and incurring the costs associated with design. When the site-specific remedy is undergoing design, more detailed information will be available.

## Master Comment 5.42

The commenter provides several direct quotes from the NAS NRC, *A Risk-Management Strategy for PCB-Contaminated Sediments* National Academy Press (March 2001) to emphasize their concern that the FS recognizes that dredging remobilizes PCBs to the water column, but it fails to account for this in its analysis of the protectiveness or effectiveness of dredging.

### *Response*

In other comments offered by these same authors, they acknowledged that the set of data from the monitoring of both pilot dredging projects represents the most comprehensive data set available. At SMU 56/57, the PCB loss approximated 2.2 percent of the mass removed. WDNR and EPA believe that this loss rate is the most applicable for the entire Lower Fox River, agreeing with the comment authors that: “Variations in site characteristics, the components of the remedy and their relevance to the lower Fox River, the method of sediment removal, the method and effectiveness of environmental controls, volume of sediment removed, and multiple contaminants of concern make direct comparisons between “successes” at other sites to the proposed project for the lower Fox River nearly impossible.”

Therefore, applying the loss rates from this project that removed the most highly contaminated sediment in the entire Lower Fox River to the proposed remediation would equate to a total loss of less than 650 kg of PCBs (2.2 percent of 29,259 kg PCBs). If one were to accept the comment authors’ additional claim that the annual PCB export from July 2000 to July 2001 was up to 106 kg of PCBs and that the rate of decline approximates a half-life of 9 years, over the next 20 years, more than 40 percent less PCBs would be released to Green Bay during active remediation (644 kg) than doing nothing (1,147 kg). Similarly, the target removal of 1,700 kg of PCBs from Little Lake Butte des Morts would potentially release less than 40 kg of PCBs, an amount roughly only double the amount one PRP suggested is contributed by sediments annually to the loading leaving Little Lake Butte des Morts.

## Master Comment 5.43

Commenters represented that natural attenuation should be the benchmark for evaluating remedial alternatives.

### *Response*

WDNR and EPA agree with this comment. Natural recovery has been used as the benchmark and has been used for comparison with the various action levels and several key thresholds including human health, ecological health, and transport to Green Bay. This comparative analysis is included in Section 10 of the FS.

## Master Comment 5.44

Commenters stated that when natural attenuation is compared to the proposed remedy, there is no measurable benefit to the Lower Fox River or Green Bay and that dredging has no net environmental benefit over natural recovery. The commenters go on to say that the proposed remedy would increase PCB export to Green Bay and hinder natural attenuation in OU 4.

## *Response*

WDNR and EPA disagree with this statement. Section 8 of the Lower Fox River and Green Bay FS compares the "no action" scenario to various RALs using water quality models. The results show a reduction in annual PCB loading from the Lower Fox River of over 90 percent when active remediation is conducted in OUs 1, 3, and 4.

It is possible that the commenters arrived at this conclusion by using a different water quality model than the WDNR, FoxSim. WDNR did review FoxSim and the results of that evaluation are included in Section 6.4 of this RS and in *White Paper No. 15 – FoxSim Model Documentation*.

## Master Comment 5.45

Commenters stated that a capping scenario essentially "trades" a reduction in short-term risk for a long-term increase in potential risk associated with cap failure. For dredging, there is the short-term risk of PCBs released from newly exposed sediments and long-term risk reduction associated with mass removal. Short-term versus long-term risks need to be weighed.

## *Response*

WDNR and EPA agree that short- and long-term risks need to be considered and balanced in the selection of a remedial action. WDNR and EPA have accomplished this through the comparison of remedial alternatives using the CERCLA nine criteria principles in Section 9 of the FS. The Agencies do have concerns about cap placement resulting in the bed of the Lower Fox River becoming the long-term repository for PCBs. If during the design phase of this project, information becomes available that strongly supports the construction of a cap over a portion of the OU 1 (or elsewhere), WDNR and EPA would require that appropriate cap monitoring and maintenance be part of that design. WDNR and EPA would also have to consider the appropriate fiduciary responsibility to require reconstruction or replacement in the event of cap failure. WDNR and EPA, while recognizing that some PCB mass will be released as a result of dredging, believe that the amount is not significant when compared to the amount of PCB material that is currently moving out into Green Bay and will continue unabated if no remedial action is undertaken.

## Master Comment 5.46

Commenters stated that WDNR and EPA should select an overall remedial approach that is based on capping and that allows for the sensible development and implementation of capping and other possible technologies.

## *Response*

WDNR and EPA did thoroughly evaluate capping as a remedial alternative in the Sections 6 and 7 of the Lower Fox River and Green Bay FS. In the FS for each OU, Alternative C represents dredging and Alternative F represents capping to the maximum extent possible. Capping as a technology is discussed Section 6 while Section 7 discusses how each alternative is applied to specific OUs. Section 9 of the FS then compares the possible remedial alternatives using the CERCLA nine evaluation criteria. Based on this evaluation and in consideration of the RAOs for these two OUs, dredging was selected for OU 1 while MNR was selected for OU 2.

The ROD does allow for a capping contingency in OU 1 if during the design phase of this project information becomes available that strongly supports the construction of a cap over a portion of OU 1. WDNR and EPA will consider that new information along with an evaluation of various parameters such as navigation channel location, water depth, scour potential, as well as if capping costs are less than dredging, then the Agencies would consider an alternative with a capping component.

Furthermore, any lessons learned in conducting pre-design, remedial design, and remedial implementation in OU 1 will be applied to downstream OUs. If a decision were made to allow such a partial cap to be constructed or some other technology utilized, the public would be informed.

## Master Comment 5.47

Commenters stated that the proposed remedy cites a requirement for "monitoring in perpetuity" to ensure the isolation of contaminants as a negative aspect of capping (Proposed Plan at 18). However, the Proposed Plan acknowledges that dredging will not immediately achieve target risk objectives. The proposed remedy will require long-term monitoring until the target risk reduction is achieved. Therefore, it is not a reason to reject capping as a remedial option.

## *Response*

WDNR and EPA agree that monitoring is necessary regardless of the remedial alternative selected and this is not the sole basis for not including a capping alternative. The WDNR has identified 40 years as being the period of post-remediation monitoring. If the Agencies' RAOs have not been reached by that time, then monitoring will be needed until the goals are met. An important point to make, however, is that WDNR does have an ongoing fish tissue monitoring program that used to assess the need for consumption advisories. If need be, the additional monitoring efforts could possibly be included in that program. The FS did include a Model Long-term Monitoring Plan (LTMP), which will be expanded based on the selected remedy. WDNR does not have a contaminated sediment cap monitoring program.

Post-remediation monitoring is consistent with environmental monitoring programs for capping at other sites. For example, as described in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*, the program described by the Agencies is consistent with those at two of the largest and oldest caps, East Eagle Harbor and the St. Paul Waterway in Washington state.

## Master Comment 5.48

Commenters stated that the proposed remedy recognizes the possibility of effective combinations of natural attenuation, capping, dredging, and various kinds of disposal, but that the RI/FS and Proposed Plan largely fail to present and analyze combinations of alternatives.

## *Response*

The WDNR and EPA disagree with this assessment. The FS clearly looked at and evaluated numerous technologies and combinations of technologies for remedial purposes. These technology evaluations and assessments on an OU-by-OU basis are in Sections 6 and 7 of the FS and are discussed in the Proposed Plan. For instance, Alternative F is typically a combination of capping and dredging, while the alternative in the Proposed Plan is a combination of dredging and MNR for the residual sediment in the OU where dredging is selected.

## Master Comment 5.49

Commenters stated that the overall approach used is faulty because the proposed remedy focuses on PCB mass removal rather than minimizing exposure to PCBs. River areas subject to scouring have generally lost PCB deposits over the last 50 years, which has resulted in more than 90 percent of the PCBs being found in the De Pere to Green Bay Reach.

## *Response*

This statement in not true. The Proposed Plan is based on risk reduction, not mass removal. This was explained in Section 9 of the Proposed Plan and the ROD. An incorrect assumption is that the River is a continuous depositional area. As WDNR has demonstrated in TM2g, the riverbed in OU 4 is dynamic in nature and can have significant bed elevation changes.

### Master Comment 5.50

Commenters stated that a dredging remedy for the Lower Fox River was predetermined, and that WDNR and EPA failed to consider capping.

### *Response*

The WDNR and EPA disagree with this statement. The RI/FS is an objective, unbiased analysis that resulted in the selection of a combination of dredging and MNR for the Lower Fox River and Green Bay. Capping to the maximum extent practicable was defined as a remedial alternative for all OUs. Capping areas in OUs 1 and 3 exceeded those proposed by the API Panel in their assessment (see Section 5.5.1 of this RS). Capping was considered in OU 4, but the area is less than that proposed by the API Panel due to a series of physical and institutional constraints that the API Panel did not consider. The Agencies did not select a capping remedy for OUs 1 or 2 as it is the Agencies' collective opinion that current conditions in the Lower Fox River cannot be maintained in perpetuity, and that the River, as the final repository of contaminated PCB sediments, does not conform with CERCLA. Having said that, the Agencies may consider capping as part of the ROD, provided that the physical, institutional, regulatory, and long-term fiduciary commitments outlined in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*, can be achieved.

# 5.5 Evaluation of Submitted Alternatives

## 5.5.1 API Panel

### Master Comment 5.51

Appleton Papers, Inc. provided funding to assemble an independent panel of university professors and scientists to evaluate the Proposed Plan for the Lower Fox River and Green Bay. The Appleton Paper, Inc. Panel (referred to as "the API Panel") completed a report entitled Ecosystem-Based Rehabilitation Plan (referred to herein as the "Panel Report") dated January 17, 2002 (The Johnson Company, 2002) that was submitted as part of the comments during the public response period. The Panel Report includes:

- An analysis of the Proposed Plan removal action and associated dredged decant water discharge issues;
- A conclusion that natural attenuation in the Lower Fox River as a remedial mechanism is too slow and will not achieve remedial goals;
- An alternative proposal to the Proposed Plan that includes capping of substantive sections for OUs 1, 3, and 4 (over 6 to 10 years);

- A proposal that would create/enhance fishery and water-dependent wildlife habitat in OUs 1, 3, and 4 on the capped surface;
- Continued reliance on the navigational dredging in OU 4 as a mechanism for PCB removal;
- Long-term monitoring plan for insurance of cap integrity (physical, chemical) and habitat;
- Long-term institutional/financial stewardship plan (operations and maintenance); and
- Appendix with cost-supporting information for the API Panel capping proposal.

### *Response*

The WDNR and EPA appreciate the input and comments from the panel of university professors and scientists that Appleton Papers, Inc. and their former parent companies funded. The API Panel members have impressive credentials and years of experience. The Agencies regret that the API the Panel was not engaged earlier in the process and was not given the opportunity to work with WDNR and EPA prior to the release of the Panel Report. The WDNR was not informed of the existence of the API Panel until the Proposed Plan was released. More details on comments from the API Panel are included in other sections of this RS.

There are statements made by the API Panel that the Agencies agree with. For instance, the API Panel agreed with the RAOs defined by WDNR and EPA. The API Panel agrees natural recovery will not be effective for rapid risk reduction except in conjunction with other remedial work. The API Panel has also stated that the Lower Fox River has the appropriate river system characteristics for dredging.

There are also conclusions that are incorrect or show a lack of either regulatory or site-specific knowledge that may be problematic. For instance, the API Panel recommended adding a restoration component to the RAOs. WDNR and EPA agree ecosystem restoration and rehabilitation are critical components for the Lower Fox River and Green Bay. However, these issues are being addressed by the NRDA that WDNR is working on with other trustee agencies, including the USFWS and the Menominee and Oneida Tribes. This is a legally distinct issue. The API Panel states that wastewater effluent limitations will be a rate-limiting step and result in a much longer period of time to complete the dredging work. The Agencies strongly disagree with this statement; there are no limits to dredge decant water discharge. The Agencies (including the resource trustees) do not agree that the proposed capping represents a significant habitat improvement. Finally, WDNR and EPA do not agree that navigational dredging in the area referred to as OU 4B would be acceptable for a remedial solution. There remain significant PCB mass and contaminated sediments in that area despite years of ongoing navigational dredging. The API Panel does not consider the continuing burden on the USACE and the Port of Green Bay in their proposal.

The Agencies regret the loss of the opportunity to work with the API Panel earlier in the process. In order to have effectively evaluated their alternatives, the Agencies would have preferred that the alternatives use consistent models, consistent application of regulatory and institutional conditions in the state of Wisconsin. It appears to the Agencies that the API Panel had only limited time and their lack of site-specific knowledge and regulations as well as their unfamiliarity with the proposed remedy, the supporting documents such as the RI/FS and BLRA, and not having any detailed knowledge of Wisconsin regulations were significant handicaps to the development of their plan. It is also unfortunate that the Wisconsin contingent of the API Panel was not bought on board until the API Panel had already completed a majority of its work.

As part of this RS, a series of White Papers were written specific to the API Panel's report. These are briefly discussed in summarized Master Comments, below. The Agencies also received a large number of comments from the Fox River RP's, and the general public on the Panel Report. These are all discussed in the ensuing comments, below.

# Wastewater Treatment

## Master Comment 5.52

The comment authors claimed that the dredging recommended in the Proposed Plan was not viable because the quality and quantity of wastewater generated in the dredging process could not comply with water quality standards and associated WPDES permit limits, even using the most advanced wastewater treatment process. The wastewater quantity and quality limitations would, therefore, restrict the allowable wastewater discharge rate, thereby decreasing the allowable dredging rate and increasing the dredge schedule from the 7 years estimated in the Proposed Plan to as much as 60 years. Based on these assumptions the comment authors concluded that in-place sediment capping was the only viable alternative for remediation of the Lower Fox River sediment.

### *Response*

It is the Agencies' position that the wastewater limitations imposed by the Panel Report are unfounded. In response to these comments the WDNR analyzed the assumptions used to support the comment conclusions, and performed an evaluation to determine if the expected dredge process wastewater characteristics and volumes would restrict or limit the viability of the Proposed Plan as claimed in the comments. The complete analysis is presented in *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits*. This analysis concludes that dredge process wastewater quantity and/or quality do not restrict the viability of dredging as recommended in the Proposed Plan, and do not, by themselves, justify the API Panel's alternative capping proposal. This evaluation essentially concludes that the expected quality and quantity of the dredge process effluent will comply with Water Quality Based Effluent Limits (WQBEL), and will not restrict the effluent discharge rate or associated dredge schedule. The expected effluent quality and quantity do not, therefore, limit the viability of the proposed remedial dredging project.

The comments assume that the wastewater discharge rate and quality are limited by the Lower Fox River's assimilative capacity and applicable Water Quality Standards and associated permit limits. In response, the WDNR's Bureau of Watershed Management completed two evaluations of the need for WPDES permit limits, copies of which are contained in *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits*. The first evaluation addressed the need for WQBELs for toxic compounds, and the second evaluation addressed Biochemical Oxygen Demand/Dissolved Oxygen (BOD/DO) issues. The WDNR evaluated effluent quality data and bench-scale test Priority Pollutant data from the Lower Fox River Deposit N and SMU 56/57 demonstration projects, along with the estimated discharge rates contained in the Proposed Plan and those estimates provided in the comments. Since the same sand filtration/carbon adsorption technology or equivalent wastewater treatment technology applied in the demonstration projects is proposed for full-scale remediation, it is assumed that the demonstration project effluent quality would be similar to and representative of full-scale effluent quality.

This analysis concluded that the BOD load from the dredge process wastewater would only use a small fraction of the available Lower Fox River BOD assimilative capacity; therefore, effluent BOD would not restrict implementation of the Proposed Plan. The analysis also concluded that PCBs, mercury and ammonia were the only other substances of concern. It was determined that PCB and mercury limits could be calculated using the alternate limit approach provided in Wisconsin Administrative Code (WAC) NR 106.06(6), which would not restrict the wastewater discharge rate or dredge schedule contained in the Proposed Plan even at the much higher API Panel-estimated discharge rates. Expected effluent ammonia concentrations were evaluated and a determination made that they were well below expected permit limits so ammonia limits would not likely be needed. This analysis concluded that the expected effluent quality generated from implementation of the Proposed Plan would not limit the wastewater discharge rate or the associated dredge rate or schedule. Wastewater discharge rates or permit limitation do not prevent implementation of the Proposed Plan.

Additional significant specific conclusions from *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits* include:

- The wastewater quality achieved from the Lower Fox River Deposit N and SMU 56/57 demonstration projects provides the best representation of the effluent quality expected from the full-scale dredging of the Lower Fox River. These data should be used for estimating expected effluent quality not those assumed by the comment authors.

- Effluent quality would not limit the ability of the project to comply with expected wastewater WPDES permit limits.

- Effluent quality would not restrict the expected effluent discharge rate based on the Lower Fox River assimilative capacity for cadmium, dieldrin, endrin, mercury, or any other parameter.

- WQBEL for Toxic and Organoleptic compounds regulated under WAC NR 106, are only needed for PCBs and mercury.

- PCB and mercury WQBELs will be determined using the Alternate Limit procedures provided in WAC NR 106.06(6), because background Lower Fox River concentrations of PCBs and mercury exceed water quality standards.

- The Lower Fox River assimilative capacity for BOD is indeed fully allocated; however, much of that capacity is unused by the permitted dischargers. Effluent from full-scale implementation of the proposed dredging plan would only use a small portion (less than 10 percent) of the unused or available assimilative capacity of the River.

- A significant portion of unused capacity is held by the PRPs and can be formally or informally reallocated to the discharge of the remediation project.

- Effluent quantity estimates contained in the comments are not reasonable, do not limit the allowable dredge rate and would not extend the dredge schedule beyond that estimated in the Proposed Plan.

- Discharges from two pilot dredging projects have been permitted under Wisconsin regulations.

More detailed responses to each of these "bullets" items are provided below in Master Comments 5.53 through 5.60, which address whether the expected effluent quality and quantity can comply with expected permit limits.

Finally, as a general response, the Agencies requested the Dr. Michael Palermo, an internationally recognized expert in both capping and dredging, evaluate the restrictions imposed on a dredging alternative by the API Panel. In *White Paper No. 6A – Comments on the Panel Report*, Dr. Palermo concludes that "the (Panel) report seems to paint an overly optimistic picture for capping and an overly pessimistic picture for dredging. The rate at which dredging is assumed to occur is severely hampered by an assumed constraint on river assimilative capacity which would likely not be imposed on a major remedial project."

## Master Comment 5.53

Commenters stated that remediation process wastewater must be treated to meet the most restrictive federal and state water quality standards and requirements prior to discharge to the Lower Fox River and that WPDES rules preclude the issuance of a discharge permit if a discharge will not attain water quality standards and that water quality standards for Bioaccumulative Chemicals of Concern (BCCs) for new or increased discharges must be the most stringent parameters contained in Chapter NR 105.

## *Response*

The API Panel commented that remediation process wastewater must meet applicable state and federal requirements, and that WPDES rules preclude the issuance of a discharge permit if the discharge will not attain Water Quality Standards (WQS), and that WQSs for BCCs for new or increased discharges must be the most stringent standard contained in Chapter NR 105. The WDNR agrees that any wastewater discharge must meet state and federal requirements but does not agree that those requirements restrict the wastewater discharge to the extent concluded by the API Panel. This comment contains two major issues requiring a response.

The first issue is that of whether the remediation process wastewater discharge should be considered a new or increased discharge. Legally, the discharge of remediation process wastewater could be considered a new or increased discharge, however, realistically the discharge is not new and is not a net increase, since the sediment is already in the Lower Fox River and contributing contaminants to the system. In fact, another API Panel comment points out the placement of the Lower Fox River and inner Green Bay on the Clean Water Act's Section 303 (d) list, as impaired waters not currently meeting Water Quality Standards, is in part due to the sediment contribution of PCBs, DDT, dieldrin, arsenic and mercury. Although there may be a short-term increase of contaminants in the water column from the dredging process, the net long-term reduction in the overall presence and contribution of contaminants from the sediment outweighs the short-term increase. It is, therefore, most appropriate to view the remedial dredging project as an action to reduce or eliminate an existing discharge of contaminants. Although this view does not actually change how limits are calculated under Wisconsin regulations it is important in maintaining perspective of the project goal to remove contaminants, and their associated impacts, which are already present in the River system.

The second issue is that of whether Wisconsin's regulations limit the WDNR's ability to issue a WPDES permit in this case, and if the most restrictive permit limits would apply. Wisconsin rules do not require the application of the most restrictive WQS as the permit limit in cases where the receiving water background concentration exceed the WQSs. Chapter NR 106 is the WAC containing the requirements for the calculation of water quality based effluent limits for toxic and organoleptic substances discharged to surface waters. NR 106.06(6) establishes the condition under which alternative limits based on background concentrations are determined and provides the flexibility to apply a Net Environmental Benefit concept when addressing situations such as this, where the contaminants are already in the system. This section of the code essentially says that whenever background concentrations for toxic or organoleptic substances in the receiving water exceed the applicable WQS, and at least 10 percent of the source water is from the receiving stream, the effluent limit for that substance may be set at the background concentration, or an alternate limit or requirement may be determined. An alternate limit or requirement may be determined if the discharger's relative contribution of the mass of the contaminant to the receiving water body is negligible in the best professional judgment of the WDNR, and if the WDNR judges that Best Demonstrated Treatment Technology Reasonably Achievable is provided. The alternate limit or other requirement may include one or more of the following permit conditions, a numerical limit (which can be greater or lower than the WQS), a monitoring requirement, or a cost-effective pollutant minimization program (which could include a specific treatment technology or performance standard).

Since the Lower Fox River is actually l00 percent of the source water (far greater than 10 percent), and background concentrations exceed the WQSs for

PCBs and mercury, which are toxic substances subject to the provisions of NR 106, alternative limits are appropriate for these substances. DDT and dieldrin were not detected, and arsenic was either not detected or not present at levels requiring permit limits in the Deposit N and SMU 56/57 demonstration project effluents. Application of the same or similar technology utilized in the demonstration projects is considered by the WDNR to be Best Demonstrated Treatment Technology Reasonably Achievable, and the PCB and mercury mass contained in the wastewater discharge are considered negligible. Therefore, the application of alternative limits or requirements other than background concentrations is reasonable, appropriate and fully in conformance with existing rules.

## Master Comment 5.54

Commenters stated that treated wastewater generated in the remediation process (at the rate estimated by the API Panel of 4.3 million gallons per day (mgd) in OU 1, and 23.7 mgd in OUs 3 and 4) even using the most advanced treatment technology can not achieve the applicable Water Quality Standards and associated permit limits.

## *Response*

The API Panel commented that achieving compliance with expected WQBEL would require wastewater treatment far exceeding Best Demonstrated Available Technology (BDAT), which would require the application of unproven technology with many associated risks. The API Panel's report includes a table (Table B-4) comparing the expected performance from BDAT treatment to anticipated WPDES Permit WQBELs, which showed compliance with WQBELs was not achievable. Although an interesting academic exercise, this analysis and conclusion are not appropriate for the proposed sediment remediation project, since there is Deposit N and SMU 56/57 demonstration project effluent priority pollutant data available documenting wastewater treatment performance which is orders of magnitude better (lower) than those cited for BDAT in the report, and below WQBELs for all parameters except PCBs and mercury. Substituting the Lower Fox River demonstration project data for the BDAT data in the report reveals that the application of the same or equivalent technology utilized in the Lower Fox River demonstration projects can achieve compliance with WQBELs. This technology is not unproven but is standard technology applied in similar remediation projects around the world.

## Master Comment 5.55

Commenters also felt that treated wastewater from the Demonstration Projects did not comply with WPDES permit limits.

## Response

The Panel Report also commented that the demonstration projects did not meet applicable WPDES permit limits. Although, there were instances where effluent quality exceeded permit limits, a general characterization that the projects were not compliant does not accurately represent the typical effluent quality and treatment performance that was achieved. The WDNR's overall assessment of the project performance is that substantial compliance was achieved for all parameters except BOD, which frequently exceeded the permit limit of less than 2 mg/L in the SMU 56/57 project. Although the BOD limit was exceeded, the project BOD discharge used only a small percent of the available assimilative capacity of the Lower Fox River. The BOD issue will be addressed in full-scale remediation project permitting by temporary transfer of unused assimilative capacity from other permitted dischargers responsible for the discharge of PCBs.

The Panel Report itemized the following violations for each of the projects:

- For Deposit N, the Panel Report claims WPDES permit limit exceedances for the PCB weekly average concentration and mass, the BOD weekly average concentration, and the TSS monthly average concentration. Detailed review of the Deposit N permit and discharge data reveal that PCB weekly average concentration and mass limits were not exceeded because the permit does not contain weekly average limits, and only contains monthly average limits which were not exceeded. Review of the effluent BOD data shows that all the weekly values were less than the level of detection (LOD less than 2 or less than 3 mg/L) except for three results of 2, 3, and 5 mg/L. Review of the TSS effluent data revealed monthly average TSS concentrations (for the 5 months of discharge in 1998 and 1999) were 0, 1.2, 3.1, 0.96, and 0.87 mg/L, none of which were violations. It is not clear why the Panel Report claimed the monthly average concentration limit was exceeded, except that in the first 5 daily analysis the TSS results were all reported as less than the LOD at an LOD of less than 8.8 or less than 10 mg/L. Table 5 of the Panel Report presents the actual discharge value as " <1 – <8.8" which when compared to the monthly average limit of 5 mg/L could, if one assumes the true value was between the LOD and the 5 mg/L, be considered a violation. The LOD of less than 8.8 is an unacceptably high LOD and was subsequently reduced to less than 1 mg/L beginning the sixth day of operation. Based on this review, the Deposit N wastewater treatment is considered to be in substantial compliance with its WPDES limits and to have consistently achieved a high-quality effluent.

- For SMU 56/57, the Panel Report claims that WPDES permit limits were exceeded for PCBs, the TSS daily maximum concentration (6 times), and the mercury monthly mass limit, and long-term average values for both TSS and BOD. Review of the PCB effluent data reveals that all of the weekly PCB analyses results were less than the LOD, at an LOD of less than 0.33 or less than 0.26 mg/L, except for one value of 0.37 mg/L. It is not clear how this could be considered a violation of the monthly average permit limit of 1.2 mg/L. Review of the effluent TSS data shows that the daily maximum and monthly average permit limits were exceeded in the first month of the 1999 project due to problems encountered with the design and operation of the wastewater treatment system. Corrective modifications were completed in about the sixth week of the project, after which effluent TSS concentrations were consistently maintained at a daily average concentration of between 2 and 4 mg/L, except for two results at the end of the project. The effluent TSS in the second year of the project averaged well below 5 mg/L with only one daily value greater than 10 mg/L. Review of the effluent BOD data shows that in 1999 the average BOD was 11.5 mg/L, except that after the treatment system modifications were completed in the sixth week, the average was about 7 mg/L. Although this exceeded permit limits, it was only a small fraction of the unused assimilative capacity available in the River.

Review of the effluent mercury data showed the average concentration was 16.5 ng/L in the 1999 project, and in the 2000 project mercury concentrations in 14 of the 19 samples were less than the LOD of 0.1 ng/L, and five values were between 0.1 to 0.45 ng/L. The year 1999 effluent mercury monthly mass discharge did exceed the permit limits because average concentration was 16.5 ng/L instead of the 5.6 ng/L (background) upon which the mass limit was calculated. The year 2000 effluent mercury is well below the 5.6 ng/L background level as are the Deposit N effluent concentrations. The alternate limit process in NR 106.06(6) as previously discussed does allow flexibility in setting limits greater than background; however, prior to considering an alternate limit greater than background, wastewater treatment system design similar to the Deposit N and SMU 56/57 2000 projects would need to be considered.

## Master Comment 5.56

Comments claimed that the expected wastewater discharge rate and quality would exceed the assimilative capacity of the Lower Fox River. Assuming the very best treatment results reported, the assimilative capacity of the River restricts the maximum discharge rate to 4.25 mgd, based on assumed treated effluent concentrations of dieldrin, endrin, cadmium, and mercury.

## Response

The Panel Report concludes the assimilative capacity of the Lower Fox River would limit the discharge rate of sediment remediation process wastewater to 4.25 mgd, based on assumed effluent concentrations of dieldrin, endrin, mercury, and cadmium. It appears these assumed contaminant concentrations were obtained from a 1985 text authored by J. W. Patterson (a member of the API Panel) and were characterized as the best reported wastewater treatment results. Using these assumed concentrations, the maximum wastewater discharge rate, which would not exceed the assimilative capacity of the River, was calculated to be 8.4 mgd for cadmium, 1.25 mgd for mercury, and 3.12 for endrin producing an average of 4.25 mgd. Dieldrin had a much lower assimilative capacity based discharge rate of 0.04 mgd, but was discounted in their report. The 4.25 mgd average along with the API Panel-estimated wastewater generation rate of 4,100 gal/cy of dredged sediment (five times the Proposed Plan estimate) was used to calculate that the dredge rate would be restricted to 1,050 cy/day, extending the dredge schedule from about 7 years to 37 to 60 years. Although the Panel Report assumed contaminant concentrations may be suitable to use when site-specific data is not available, they are not appropriate to use in this case given the availability of substantial demonstration project data from the Lower Fox River. As part of the demonstration projects, four separate sets of treated effluent samples were analyzed for all the priority pollutants. Two were from bench-scale tests using Deposit N and SMU 56/57 sediment as part of the pre-design phase of the projects. The two other analyses were completed on effluent collected during normal operation of the actual Deposit N and SMU 56/57 demonstration projects. Dieldrin and endrin were not detected in any of the four analysis at a LOD 10 to 100 times lower than the Panel Report assumed value. Three of four samples did not detected cadmium at an LOD of 20 to 50 times lower than the assumed value, with one detected cadmium value at one-tenth the assumed value. Mercury was only done on three of the four priority pollutant analyses, however, it was also analyzed weekly during the demonstration projects. Mercury was not detected in any of the three priority pollutant analyses with LODs of 10 to 1,000 lower than the assumed value. During the SMU 56/57 year 2000 demonstration project about 19 mercury samples were collected of which 14 had no detects at an LOD 2,000 times lower than the assumed value, and five values had detected concentrations, the highest of which was 500 times lower than the assumed value. The Deposit N project effluent mercury values were mostly detectable at levels similar to those detected in SMU 56/57 2000. Deposit N and SMU 56/57 (1999) influent wastewater mercury analysis was also done on samples collected just prior to the wastewater treatment process which showed the influent mercury concentrations were also far below the assumed values used by the API Panel for treated effluent.

It is not clear from this comment why mercury was included in this analysis since it was already identified as having no available assimilative capacity because River background concentrations already exceed the mercury WQS. As discussed else where in this response, since mercury is present in the background receiving water at concentrations exceeding the WQS, Chapter NR 106.06(6) allows for effluent limits at or above background concentrations. The permit limits set for mercury in the demonstration projects were based on background concentrations.

Replacing the Panel Report's assumed contaminant values with the data generated in the demonstration projects, but keeping all the other assumptions the same, increases the assimilative capacity based wastewater discharge rate at least by a factor of 10, from 4.25 mgd to 42.5 mgd. This is well beyond the maximum discharge rate of 23.7 mgd estimated by the Panel Report based on the Proposed Plan's dredge rate of 5,770 cy/day (assuming their wastewater generation rate of 4,100 gal/cy). Based on this analysis, the WDNR does not believe that the Lower Fox River's assimilative capacity for cadmium, mercury, dieldrin, and endrin will limit the wastewater discharge rate and associated dredge rate and will, therefore, not extend the dredge schedule beyond the 7 years estimated in the Proposed Plan.

## Master Comment 5.57

Commenters stated that no assimilative capacity is available for BOD since that capacity is already fully allocated.

## *Response*

The API Panel commented that no assimilative capacity for BOD is available because that capacity is already allocated to existing dischargers. Although the River is fully allocated, much of that allocated capacity is not used, so excess allocation could be temporarily transferred to the sediment remediation project, especially since much of the unused allocation is held by the responsible paper companies. Although it is widely understood that the existing permittees only used a portion of their allocated capacity, no actual calculation to quantify that unused capacity had been done. In response to this issue, WDNR staff have evaluated the last 3 years of discharge data and calculated on a daily maximum permit limit basis the least amount of unused Wasteload Allocation (WLA) for each of the permittees in each of the three WLA clusters. This analysis documented there was substantial unused WLA capacity available in all three clusters for the sediment remediation project. Cluster I roughly corresponds to OU 1, and Cluster II contains most of OU 2, and Cluster III contains all of OUs 3 and 4. Cluster I extends from the outlet of Lake Winnebago to just upstream of Appleton Lock 1 and dam, and has a minimum unused WLA of 10,688 lbs/day. Cluster II extends down stream from the Appleton Lock 1 and dam to just below the Rapide Croche lock and dam and has a minimum unused WLA of 29,536 lbs/d. Cluster III extents from Cluster II to the mouth of the Lower Fox River at Green Bay and has a minimum unused WLA of 39,531 lbs/d. This analysis looked at the very worst-case scenario and did not factor in the multiplier applied to daily maximum permit limits. Assuming application of the permit limit multiplier and assuming normal flows and temperatures, the actual unused WLA would probably be twice that shown here.

In order to calculate the BOD load expected from the remediation project, a design flow of 1.4 and 10 mgd, which is twice the flow rate estimated in the Proposed Plan for OU l and OUs 3 and 4 was assumed. Next an average effluent BOD concentration of 15 mg/L was selected. The 15 mg/L value is very conservative because it is one of the highest effluent BOD values reported and is two to three times higher than the average BOD concentration experienced in the SMU 56/57 demonstration project. Deposit N effluent BOD values were all but a few less than the level of detection less than 2 or less than 3 mg/L). Assuming a discharge rate of 1.4 mgd in OU 1 and a discharge rate of 10 mgd in OUs 3 and 4, with an effluent BOD concentration of 15 mg/L, results in a discharge of l75 lbs/d in OU 1 and a discharge of about 1,300 lbs/d in OUs 3 and 4. Comparing these values to the minimum unused BOD WLA of 10,000 lbs/d in OU 1, and the minimum unused BOD WLA of 30,000 to 40,000 lbs/d in OUs 3 and 4, it is clear the remediation project discharge would have no significant impact on water quality and would not limit the feasibility of the dredging project.

## Master Comment 5.58

Commenters felt that the wastewater generation rate should be 4,100 gallons/cy of dredged sediment, which is five times the proposed rate used in the Proposed Plan. This assumption increases the volume of dredge process wastewater needing treatment from the 0.7 to 5.0 mgd estimated in the proposed plan to the API Panel estimate of 4.3 to 23.7 mgd.

## *Response*

The Panel Report commented that the dredge process wastewater generation rate should be estimated from the history of other projects which was presented in Table B-1. They concluded the more appropriate wastewater generation rate to use for planning is 4,100 gal/cy, which is the average of the projects in Table B-l, instead of the 542- 880 gal/cy they say WDNR assumed. Using the API Panel value of 4,100 gal/cy results in about a five-fold increase in wastewater volume needing treatment, increasing the estimated wastewater discharge rate to 4.3 mgd in OU l and 23.7 mgd in OUs 3 and 4. Review of the Table B-l project wastewater generation rates showed that seven of the eight projects had wastewater generation rates between 1,000 gal/cy and 5,600 gal/cy with an average of 2,842 gal/cy. One project showed a wastewater generation rate of 11,111 gal/cy, which is about twice that of the next highest value of 5,576 gal/cy, resulting in an average of 4,100 gal/cy. This single value clearly skews the average and does not appear appropriate to use, especially given the small sediment volume dredged in that project. The SMU 56/57 project wastewater generation rates were about 1,300 gal/cy in year 2000, and 2,400 gal/cy in year 1999, averaging 1,734 gal/cy for the total project. The year 2000 SMU 56/57 project is considered to be more representative of a full-scale operation because it did not have the same problems encountered in 1999 which due to the short duration and smaller dredge volume probably skewed the wastewater production rate to the high side. Deposit N in the first two larger phases of the project ranged from 1,843 to 2,705 gal/cy, with an overall (Phases 1 through 4) average of about 3,000 gal/cy. Given the small volume (approx. 11,000 cy) of sediment dredged, Deposit N is considered less representative of a full-scale operation than is SMU 56/57 in year 2000. The Lower Fox River demonstration project wastewater production rates are considered by the WDNR to be more representative than that estimated by the Panel Report since they were actually done in the Lower Fox River environment, and are not skewed by data from dissimilar projects. It is also expected that full-scale operation efficiency would exceed that of the demonstration projects due to the scale of the project (7 million cy), the longer duration, possible application of greater efficiency technology, and greater contractor familiarity with the specific Lower Fox River conditions. Based on this analysis, it is reasonable to assume that wastewater production rates will be at a minimum less than one-half to one-third of the API Panel estimate, resulting in wastewater volumes of less than 2 to 10 mgd. Although the WDNR believes the wastewater volumes will be far less than those estimated by the API Panel, the WDNR has concluded, in the previous analysis, that even if the flows were as high as the Panel Report estimated, there would not be any limitation to the dredge rate and associated dredge schedule.

## Master Comment 5.59

Commenters stated that assuming a maximum wastewater discharge rate of 4.25 mgd and a wastewater generation rate of 4,100 gal/cy of dredged sediment, results in a maximum dredge rate of 1,050 cy/day, which extends the estimated dredge schedule from the Proposed Plan estimate of 7 years to as much as 37 to 60 years.

## *Response*

The Panel Report commented that restriction of the wastewater discharge rate to 4.25 mgd, with an assumed wastewater generation rate of 4,100 gal/cy of dredged sediment, would result in a maximum dredge rate of 1,050 cy/day, which would extend the projected dredge schedule from 7 years to as much as 37 to 60 years. As shown in the Responses to Master Comments 5.55 and

5.57 discussions, the WDNR believes the wastewater discharge rate is not limited to 4.25 mgd, and the wastewater production rate will be much lower than 4,100 gal/cy, therefore, the dredge rate is not limited to 1,050 cy/day and the dredge schedule will not extend beyond the Proposed Plan's estimate of 7 years. The WDNR believes that the dredge rate of 5,770 cy/d estimated in the Proposed Plan is a reasonable assumption. A comment made by one of the Wisconsin contributing reviewers to the API Panel, at the May 2002 Science and Technical Advisory Committee (STAC) meeting, indicated that Donald Hayes, a member of the API Panel, said that OU 4 could be dredged in 2 years if the sediment was placed in a confined disposal facility (CDF). Although it was not explained how this assumption fit with the wastewater discharge concerns of the API Panel, it does support the conclusion that the proposed dredge rate of 5,770 cy/day is not unreasonable, and that even greater dredge rates may be technologically feasible.

## Master Comment 5.60

Some commenters claimed that extending the dredge schedule to as much as 60 years results in far greater PCB exposure and environmental impact than would capping, making capping a better solution.

## *Response*

The Panel Report commented that extending the dredge schedule to as much as 60 years resulted in far greater PCB exposure and environmental impact than would capping, which is estimated to takes 10 years. Based on the previous analysis and discussion the WDNR believes the dredging schedule will not be extended beyond the Proposed Plan estimate of 7 years due to wastewater discharge limitations. The proposed dredging plan would not, therefore, result in greater PCB exposure due to project schedules, but instead would take less time to implement and would address more of the sediment surface area than would the API Panel capping proposal.

# Natural Attenuation

## Master Comment 5.61

The Panel Report noted that the process of natural sedimentation in the River occurs at a rate too slow to isolate areas affected by high PCB concentrations, or to achieve the RAOs in an appropriately short period of time. "For these reasons, the Panel does not believe that natural recovery could serve as a feasible primary or singular remedy" (API Panel Report, Page 7; The Johnson Company, 2002). However, the API Panel did accept an annual rate of 10 percent per year as part of its determination and evaluation of remedial success.

### *Response*

The WDNR and EPA agree with the API Panel in stating that natural attenuation will proceed too slowly to meet the RAOs. The decision to proceed with active remediation was based upon risk reduction and time necessary to reduce or eliminate consumption advisories for fish. The Agencies concur that the processes involved in natural recovery are not amenable to an effective and expeditious remediation of the Lower Fox River. The Agencies do not believe the API Panel's assumed 10 percent annual reduction in PCB sediment concentrations.

## Risk Reduction

### Master Comment 5.62

That risk reduction would be more quickly and reliably achieved with the capping alternative proposed is a central argument of the Panel Report. The API Panel contends that capping would isolate the PCB contamination from biological availability, achieve the SWAC, lower resuspension in water, and in general achieve risk reduction with greater certainty and speed than the Proposed Plan removal action.

### *Response*

The Panel Report proposal does not achieve the risk reduction goals set by the Agencies for any of the OUs. The risk reduction aspects of the Panel Report are examined in *White Paper No. 5A – Responses to the API Panel Report*. The net result is that the API Panel's alternative is less protective to human health and the environment, does not meet the CERCLA preference for removal and treatment, has no demonstrated certainty in the design, no demonstrated surety in its construction costs, and does not account for long-term responsibility for cap failure.

In the Proposed Plan, the Agencies evaluated the range of potential RALs in the FS, and selected 1 ppm based upon the nine CERCLA criteria (see Master Comment 9.1). An RAL of 1 ppm would result in SWACs of 0.19, 0.27, and 0.16 ppm in OUs 1, 3, and 4, respectively. The API Panel proposed that a SWAC of 0.5 ppm be used as a design criterion. The proposed SWAC was not based on a site-specific assessment of risk, but rather on an engineering "implementation efficiency" estimation. This is a fundamental requirement of CERCLA, and a finding of the NRC committee. When examined on a similar basis, the actual SWAC in the API Panel's proposal for the three OUs are 0.71 ppm for OUs 1 and 4, and 0.56 ppm in OU 3. The comparable RAL in the FS to achieve the API Panel-generated SWACs is 5 ppm. Thus, the SWACs in the Panel Report are four times greater than the risk reduction goal identified in the Proposed Plan. The net result is: (1) the API Panel's proposal does not meet the risk reduction goals of the Proposed Plan; and (2) comparison by the

API Panel to the Proposed Plan risk reduction, technical implementability, or costs are erroneous – the area and volume covered in the Panel Report is only one-half of that in the Proposed Plan. As noted by Dr. Palermo, “A direct comparison of SWAC reduction rates for two alternatives with differing action levels is inappropriate when those action levels drive the timeline for completion of the respective actions.”

# Cap Design

## Master Comment 5.63

The Panel Report proposed alternate criteria for cap design from the FS, and applied what they deemed to be appropriate cap thickness and armoring throughout the River. They maintain that the alternate designs that are presented in the Panel Report (e.g., design thickness, materials, armoring) follow procedures defined in the EPA and USACE guidance documents (Palermo et al., 1998a, 1998b). They develop and present different designs for different deposits/SMUs for OUs 1, 3, and 4 using the 5 ppm RAL (see Master Comment 5.61) footprint. The costs presented in the Panel Report are then compared to the Proposed Plan results, with a conclusion that the API Panel proposal is less expensive to implement than that of the Proposed Plan

### *Response*

WDNR and EPA believe that the while capping is and can be an appropriate part of a remedial design, it should be a part of a remedy component, and not the sole component as is offered in the Panel Report. Furthermore, the Agencies believe that the design(s) provided by the API Panel are not technically sound; the design is based upon computer models and have never been implemented anywhere in the world. The API Panel cannot point to a single cap with this design that has been implemented successfully in any environment, much less a riverine environment.

When compared on an equal RAL basis, the FS capping alternatives for OU 1 cover the same areas and more than those proposed by the API Panel (see FS Figures 7-17 and 7-30, relative to Panel Report Figures 7 and 8). Ice scour also remains a considerable constraint on cap placement in water depths of 3 feet or less. In addition, WDNR fisheries biologists indicate that as a habitat consideration to discourage carp, a minimum water depth of 3 feet should be maintained. This appeared to be considered by the Panel Report for OU 1. In addition, Dr. Palermo’s *White Paper No. 6A – Comments on the API Panel Report* and *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* point out that long-term lake level changes (from +5 to -1 feet) should be accounted for in designing for these restrictions for OU 4.

Other technical issues were equally of concern to the Agencies. As pointed out by Dr. Palermo, technical issues for capping not fully considered in the report include:

- The rationale in selecting total cap thickness,
- The basis of design for the chemical isolation component;
- Consolidation-induced advection;
- Potential mixing of contaminated sediments and cap material; and
- Constraints on capping in shallow-water areas

A detailed design effort for any selected capping remedy should address these and all pertinent design considerations. While the report considers some design issues, the information on cap design is not clearly presented and there is insufficient information offered to verify the proposed design with respect to all the issues.

The total thickness of a cap, and the composition of the cap components, should be based on an evaluation of all the pertinent processes for the Site and the ability of the design to achieve the intended functions of the cap. Some of the processes for design of cap components can be evaluated rigorously with models, etc., but others require engineering judgment and experience. A major common thread for all the area-specific designs is a 12-inch total thickness (see comment above). Another common thread for most of the designs is a 3-inch fine sand layer, which is presumably intended to be the chemical isolation layer. However, several of the areas show a design of only 12 inches of coarse sand. A coarse sand would normally have little or no fine fraction, therefore little or no adsorptive capacity for chemical isolation. If an additive such as activated carbon were used to boost adsorptive capacity, there would be a high potential for separation from a coarse sand during placement. Dr. Palermo concludes that "the design for these areas therefore seems non-protective from the standpoint of chemical isolation," and that "… in my judgment, a total cap thickness of 12 inches seems non-conservative for a major site like the Fox River."

A summary of all capping projects to date is provided in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*, shows that the caps built to date average within the 2- to 3-foot range of sand thickness. All of these caps are in lakes, estuaries, or deeper water not subject to erosional actions. Given all of the data above, the Agencies judge the Panel Report design to be technically deficient and too broadly applied across at least OU 4.

## Master Comment 5.64

The API Panel, and several of the RPs, suggest that the Panel Report proposal is more implementable than the Proposed Plan remedy with issues related to technical and administrative feasibility. They contend that: (1) the ability to construct and operate proposed technology (use and reliability), (2) ability to obtain applicable permits or meet permit requirements, and (3) degree to which coordination can be achieved, is far superior to that offered by the Proposed Plan.

## Response

WDNR and EPA disagree with the API Panel and the RPs on this comment. Ease of construction is not assured for the API Panel capping proposal. There has never been a cap constructed anywhere in the world on this scale, much less in a riverine environment. That the cap can be constructed is not an issue. When compared to the kinds, numbers, and availability of dredging equipment, the API Panel does not point out that there are less than a dozen vessels or specialized equipment for capping throughout the world. *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* shows several representative mechanisms for cap placement, but most of the caps constructed to date use split hull barges; a technology inappropriate to the Lower Fox River. The API Panel also does not mention any mechanisms for placement that would take into account the low shear strength of the sediments within the Lower Fox River, and the specialized techniques that are needed to successfully place material under these conditions. In fact, the API Panel's consultant, The Johnson Company, has encountered significant problems with shear failure at the demonstration cap project at the Pine Street Canal Superfund Site in Burlington, Vermont (Tom Fredette, USACE, personal communication). WDNR and EPA's consultant to the Lower Fox River, The RETEC Group, Inc., has successfully demonstrated capping techniques on low-shear strength sediments at two recent projects, so the Agencies are aware it can be done. The time taken to apply the material, however, is critical and probably underestimated in the Panel Report. Thus, the Agencies conclude that capping construction is not assured.

The Agencies also take issue with the statement that obtaining permits for cap construction will be easier for the Panel Report's proposal. The API Panel was perhaps not aware of Wisconsin state statutes relating to the construction, fill, or use of aquatic lands. These are described in Section 6 of *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. For properties clearly identified as state-owned aquatic lands, capping would require obtaining a Lake Bed Grant from the Wisconsin State Legislature. This is not a "simple" permitting requirement. The grant would have to go to the adjacent municipality, and the uses of any filled area would have to be specified in the legislation. A Lake Bed Grant, for example, would have to be obtained from the legislature for OU 1. It is likely that a lease would be required for maintaining a cap in perpetuity. For OUs 3 and 4, easements may need to be sought from adjacent riparian property owners. Within OU 4, the

API Panel proposed capping within the federally-authorized navigation channel. Under federal law, this is not allowed unless specifically approved by an Act of Congress. Federally, Section 10 of the Rivers and Harbors Act of 1899 (22 CFR § 403) requires permitting for any construction that would impact the course, capacity, or condition of navigable waters of the United States (Palermo et al., 1998b). Any cap would be considered as an obstruction to navigation. Finally, floodplain zoning would need to be considered with the installation of any capping project. Wisconsin statutes prohibit the siting of solid and hazardous disposal facilities within a floodway. In addition, under state statutes, if the in-water structure results in a change to the 100-year flood elevation by as much as 0.01 of a foot, easements from affected property owners need to be obtained. Given the extensive areas and elevational changes in the Panel Report's proposal for OU 4, it is likely that floodplain zoning issues would be an overriding consideration in that reach. Thus, the Agencies believe in fact that the permitting and institutional requirements for a cap as proposed by the API Panel will be more difficult to implement.

### References

Palermo, M. R., J. E. Clausner, M. P. Rollings, G. L. Williams, T. E. Myers, T. J. Fredette, and R. E. Randall, 1998a. *Guidance for Subaqueous Dredged Material Capping*. Technical Report DOER-1. United States Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Website: http://www.wes.army.mil/el/dots/doer/pdf/doer-1.pdf.

Palermo, M. R., J. Miller, S. Maynord, and D. Reible, 1998b. *Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In-Situ Subaqueous Capping of Contaminated Sediments*. EPA 905/B-96/004. Prepared for the Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, Illinois. Website: http://www.epa.gov/glnpo/sediment/iscmain

## Master Comment 5.65

The Panel Report states that capping OUs 1, 3, 4A could be achieved in 6 to 10 years time. They contrast this time with their estimates of dredging based on limits of wastewater treatment, and argue that there will be 60 years of removal action and exposure of subsurface PCBs.

## *Response*

WDNR and EPA believe that the Panel Report is mistaken on two counts: (1) there are no limitations to wastewater treatment that will effect dredging production rates; and (2) that the time needed to resolve institutional, regulatory, and construction issues will likely result in more time than the API Panel assumed in their proposal. The Agencies believe that the FS is correct in noting that there are likely to be no differences in time to achieve dredging or capping alternatives on the Lower Fox River. The API Panel's proposed capping design and projected construction timeframes are not based upon any demonstrated similar projects. The Panel Report cannot point to a single implemented cap in a riverine system in the United States, Canada, or the world that has been successfully placed, monitored, and demonstrated long-term contaminant isolation. Rather, the API Panel relied on desktop computer models to justify the specific design in their plan. Furthermore, the API Panel's estimates of dredge times are based upon erroneous assumptions on discharge water quality that would restrict dredging operations.

## Master Comment 5.66

The Panel Report maintains that their capping proposal results in achievement of the risk reduction goals defined in the RAOs, but at a cost less than the removal costs defined within the Proposed Plan. The API Panel, and several RPs, on that basis stated that the API Panel capping proposal should be the final alternative for the River, in lieu of the Proposed Plan.

## *Response*

The Panel Report errs on a number of levels in making this comparison. As noted previously, the Panel Report's proposal does not meet the risk reduction goals of the Proposed Plan, places caps at physically inappropriate areas of OU 4, and considers a design that in the opinion of the world's leading expert in capping, is non-conservative. A direct comparison of cost is not applicable; the Panel Report assumes a residual risk level that is up to four times greater than that proposed by WDNR (see *White Paper No. 5A – Responses to the API Panel Report*).

Comparative costs between the Proposed Plan and the Panel Report are examined in *White Paper No. 5B – Evaluation of API Capping Costs Report*. Based upon that analysis, the following conclusions can be drawn:

- The Panel Report does not accurately portray compare remedial costs. The Panel Report compares its alternatives developed at a less protective RAL (5 ppm) with the Proposed Plan RAL (1 ppm). The practical result of this decision is that the Panel Report develops costs for an area that is only one-half of that managed by WDNR's Proposed Plan.

- When compared at the same RAL (5 ppm), contaminated sediment removal alternatives in the FS are less expensive, or equivalent, in cost to the API Panel plan for all three OUs.

- The Proposed Plan removal alternative for OU 1 (dredge with off-site disposal), at an RAL of 1 ppm is equivalent in cost to the API Panel capping alternative.

- The Proposed Plan removal alternative for OUs 3 and 4 achieves permanent removal of PCBs from the River at a lower (more protective) RAL, but are within 23 to 25 percent of the costs proposed by the Panel Report.

- The Panel Report costs, when projected onto the 1 ppm RAL footprint, are greater than removal costs in OUs 1 and 3, and equivalent to removal costs in OU 4.

- The capping design offered by the Panel Report did not consider addition of a foundation layer, nor incorporate any safety factors. Based on engineering judgment and experience at other sites, the API Panel cap thickness requires an additional 8 to 12 inches.

- When the technical adjustments to the cap design are applied, along with an accounting for the larger remedial footprint, the cost of the API Panel cap is either greater than or equivalent to the cost of removal in all OUs.

The Agencies believe that the Panel Report conclusion, when examined on an equivalent basis to the Proposed Plan, offers less risk reduction, is similar in cost to the removal defined in the Proposed Plan, and offers the additional benefit of no long-term commitment to operations, monitoring, and maintenance within the Lower Fox River.

## Master Comment 5.67

A large number of comments were received from public and private concerns relating to the Panel Report. These included comments that supported the API Panel proposal for capping, as well as comments that were concerned about capping and preferred the removal alternative in the Proposed Plan. In addition, some commenters advocated a mixed position of capping and dredging.

## *Response*

WDNR and EPA evaluated the API Panel's capping proposal, and found that it did not meet the RAOs and risk management goals as articulated in the Proposed Plan. In and of itself, the API Panel proposal is considered insufficiently protective as follows:

1) The Panel Report does not achieve the risk management goals of the Proposed Plan. The SWAC achieved with the API Panel capping

proposal is up to four times greater than the remedy decided for the ROD. Even accepting the API Panel's calculations, the estimated SWAC is 0.5 ppm on a river-wide basis. SWACs estimated for dredging recommended in the Proposed Plan are: 0.185, 0.264, and 0.156 ppm for OUs 1, 3, and 4, respectively. Thus, the Alternative C2 for OU 1 is significantly more protective than the API Panel's capping plan. An analysis estimating time for removal of fish advisories after capping was not presented, but would be longer than the recommended alternative, since the API Panel proposes to leave untreated a significantly greater amount of material than the Proposed Plan.

2) The API Panel's assumption that dredging will be limited by wastewater discharge requirements is incorrect. The analysis undertaken by WDNR demonstrates that there are no limitations as described by the API Panel. Given this, the API Panel's premise that capping will be a more readily achieved remedial option is invalid.

3) It appears that the API Panel's analysis assumes a 2 ppm residual concentration for dredged areas, and thus the API Panel concludes dredging would yield a less protective result than their capping proposal. However the 2 ppm residual concentration estimate is erroneous. Appendix B of the FS showed an average 97 percent concentration reduction for five dredging projects. Additionally, the Hudson River White Paper (*Post-Dredging PCB Residuals [ID 312663]*) showed dredging residual concentrations 96 to 98 percent (for nine projects evaluated). Thus, based on results from these dredging projects a 96 percent contaminant concentration reduction for residual sediments is reasonable, which provides an estimate for residual PCB concentrations much less than 1 ppm. The FS (and Proposed Plan) assumed a conservative 1 ppm for dredged areas. Incidentally, one of these projects was the Lower Fox River SMU 56/57 dredging project which had a 96 percent concentration reduction – pre-dredging PCB concentrations were 50 ppm and post-dredging concentrations 2 ppm. Presumably the 2 ppm assumption by the API Panel for dredging residuals appears to be based on the absolute concentrations remaining after dredging was completed at the SMU 56/57 project. However, this does not consider the proportional reduction observed consistently on this and other dredging projects, discussed above.

4) The API Panel's discussion regarding the permanence of a cap did not consider the modification of River hydraulics because of the placement of 1 foot of capping material in the River. This would reduce the River's cross-sectional area, and therefore increase water flow velocities and potential scour. The calculations for resuspension

of capping materials also do not consider mass movement processes – that is, movement of sediments as a slurry or by siltation processes. In other words, capping material could be disrupted without necessarily being resuspended.

5) Finally, greater potential (especially long-term) for erosion due to lower lake levels anticipated in the Great Lakes due to global warming was not considered. Lower lake levels are already occurring, and expert climatologists estimate a lower Lake Michigan lake level of 1.5 to 3 feet over the next three decades and up to 8 feet by the end of this century (see attached *Executive Summary and Report Cover for the Report of the Great Lakes Regional Assessment Group, U.S. Global Change Research Program, Great Lakes Overview*, October 2000). This report also predicts a likelihood for greater variability and severity of storm (e.g., flooding) events.

## 5.5.2 P.H. Glatfelter and WTMI

### Master Comment 5.68

Alternative proposals to the Proposed Plan for remediation in OU 1 were offered by two of the PRPs on OU 1; P.H. Glatfelter and WTMI (formerly Wisconsin Tissue). Both proposals appear to have been developed in tandem, and with consideration of the report produced by the API Panel Report (The Johnson Company, 2002). The central tenant for their proposal is that active remediation is only required for Deposits A/B, and portions of Deposit POG. Active remediation would include only a partial removal of the contaminated sediments at the two deposits at an action level of PCBs greater than10 ppm, and covering the residuals with a sand cap. The companies argue that OU 1 sediments are stable, and that natural attenuation is occurring at Deposit E. Therefore, they contend that active remediation for the remainder of OU 1 is not required.

### *Response*

The alternate remedial alternatives proposed for OU 1 do not meet the risk reduction and technical requirements of the proposed remedy. The findings are presented in detail in *White Paper No. 5C – Evaluation of Remedial Alternatives for Little Lake Butte des Morts Proposed by WTMI and P.H. Glatfelter*. The Agencies do not agree with the commenters’ position that large portions of Little Lake Butte des Morts will not be subject to significant scour potential in perpetuity. Therefore, remediation must be included for all the deposits in OU 1 with exceedances of the 1 ppm RAL. More specifically, the Agencies find the following:

### Risk Reduction

The alternative proposal submitted by P.H. Glatfelter and WTMI does not meet the risk reduction goals set by WDNR and EPA. As discussed in the Proposed Plan, management of the PCB-contaminated sediments within the 1 ppm RAL will result in the target SWAC of 0.19 ppm in the OU. The resulting SWAC from the combined P.H. Glatfelter/WTMI proposal is 1.7 ppm, essentially an order of magnitude greater than that targeted by the remediation agencies. Essentially, the alternative proposes an RAL of greater than 10 ppm to achieve a SWAC of 1.7 ppm.

### Natural Attenuation

The P.H. Glatfelter/WTMI proposal relies on natural attenuation in the largest surface area of PCBs exceeding the RAL in OU 1: Deposit E. In the review of the more recent sediment data submitted by P.H. Glatfelter and WTMI (*White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples*), it was concluded that these newer data generally support the conclusion of the RI/FS and the Proposed Plan. Surface sediments within Little Lake Butte des Morts exceed the RAL of 1 ppm, and do not substantively alter the current SWAC for OU 1. The Agencies believe that these data, along with the TTA of sediment and fish tissue concentration do not support a natural attenuation alternative for Deposit E.

### Technical Considerations

Both proposals are technically implementable. It is feasible to remove the contaminated sediments within Deposits A and POG, and replace the removed sediment with a cap. However, both proposals rely on the cap thickness and design estimates provided by the Panel Report, without presenting an evaluation of post-dredge conditions. As noted in *White Paper No. 6A – Comments on the API Panel Report*, a deficit of the API Panel capping proposal is that the API Panel did not present the rationale in selecting total cap thickness, the basis of design for the chemical isolation component, consolidation-induced advection, potential mixing of contaminated sediments and cap material, or constraints on capping in shallow-water areas. There is no basis to support an engineering design for the 6-inch cap proposed by P.H. Glatfelter and WTMI on bedded sediments, much less on sediments that have been disturbed by dredging. According to Dr. Palermo's professional judgment, even a total cap thickness of 12 inches seems non-conservative for a major site like the Lower Fox River.

### Institutional and Regulatory Considerations

The proposal by P.H. Glatfelter/WTMI does not provide a discussion of any of the institutional or regulatory considerations that are discussed in the *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*. This includes determining subaqueous property rights (i.e., Lake Bed

Grant or riparian owner easement), Wisconsin statutes that regulate “fills” in the Lake Winnebago pool system (Wis. Statute 30.203), federal and state prohibitions regarding fills within a navigation channel, floodplain zoning issues under WAC NR 116, long-term operations and maintenance, as well as mechanisms for long-term fiduciary responsibility.

**Summary**

The Agencies were unable to include these proposals in the final decision because they were not sufficiently protective or not implementable. However, the Agencies have included in the ROD a capping contingency as well as a post-dredging sand cover as an option. This flexibility in the final remedy is, in part, in response to comments and/or concerns expressed associated with these proposals.

## 5.5.3 Minergy/Earth Tech and Brennan

### Master Comment 5.69

Three companies, Minergy Corporation, Earth Tech, and Brennan, submitted a conceptual design for the dredging and dewatering of the contaminated sediment above the 1 ppm RAL consistent with the proposed remedy, and then using vitrification (via GFT) for final sediment disposition instead of landfilling the dewatered sediments.

### *Response*

WDNR and EPA appreciate the time and effort these companies have clearly put into their conceptual design. However, remedy design and implementation are beyond the scope of the FS, the Proposed Plan, or the ROD. These issues are typically addressed in the remedy design and remedial action (RD/RA) phase of a Superfund project. The WDNR will try to see that these ideas are included in the design phase of this project.

## 5.5.4 AquaBlock™

### Master Comment 5.70

One commenter suggested that the capping alternative should consider the use of the clay-based AquaBlock™ sediment capping technology either as a replacement for or in concert with the granular sand capping materials currently being considered. In general terms, the commenter expected that the estimated material and placement costs associated with implementing a typical AquaBlock™ cap would be comparable to costs associated with implementing the preliminary cap design contained in the FS.

### *Response*

Many of the capping issues presented in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* would also have to be addressed for the use of this material to be used in the final remedy. This technology has not been proven for long-term effectiveness, particularly in a riverine environment. Of particular concern for application to the Lower Fox River is the generation of significant amounts of methane that could disrupt the integrity of a cap constructed from this material. The selection of capping material will be addressed during the final design of the remedy, should capping be included in the ROD.

# 6 Modeling Development and Application

## 6.1 Model Documentation Report

### Master Comment 6.1

Several commenters suggested that modeling assumptions made by WDNR were not adequately described and therefore the selection of the proposed remedy was arbitrary and capricious due to insufficient model documentation.

### *Response*

WDNR and EPA strongly disagree with this comment. There is an extensive body of information that has been developed related to fate, transport, and biological uptake of PCBs within the Lower Fox River and Green Bay. This body of information is carefully documented within the *Model Documentation Report* (MDR) and the supporting appendices. The MDR contains a comprehensive listing of all equations, assumptions, calibration procedures, and model code. In addition to the two-volume set, the MDR also includes CDs containing the working models, and all input and output files from all of the model runs performed as part of the RI/FS. The Agencies believe that the MDR provides a complete, open, and transparent set of documentation to the modeling process.

The models used within the RI/FS have been developed over multiple years as a collaborative process that included scientists and mathematicians within the Agencies, and scientists in both the public sector and the FRG. The model process was reviewed thoroughly and broadly. This included input from the USGS, USFWS, USACE, and researchers and scientists from the University of Wisconsin, University of Connecticut, and Manhattan College. The models received peer review by a panel assembled by the EPA, as well as an independent panel assembled by the American Geological Institute (AGI).

The process to evaluate models used in the Lower Fox River and Green Bay RI, BLRA, and FS were established through an agreement between the WDNR and the FRG in January 1997. The agreement established a model evaluation process (MEP) described in the *Work Plan to Evaluate the Fate and Transport Models for the Fox River and Green Bay* (Work Plan). A total of 17 separate technical memos were developed as part of the process and are provided as appendices to the MDR.

The purpose of the modeling effort was to improve the estimation and forecast of the movement of sediments contaminated by PCBs in the River and Bay, and the MDR provides a concise compilation of the models used in the RI/FS.

Models were just one tool used in the RI, BLRA, and FS to evaluate the degree and extent of contamination, risks to human health and the environment, and long-term benefits of implementing remedial approaches for the Lower Fox River and Green Bay study area. Information on other tools can be found in *White Paper No. 9 – Remedial Decision-Making in the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, and Proposed Remedial Action Plan*.

The process to evaluate model use in the Lower Fox River and Green Bay was established through an agreement between the WDNR and the FRG in January 1997. The agreement established an MEP described in the Work Plan. The Work Plan and technical memorandum prepared as part of the MEP are described in Section 2 of the MDR. The modeling effort conducted consisted of five interrelated programs to simulate the movement of PCBs in the environment:

- Lower Fox River and Green Bay interpolated bed maps that define sediment thickness, physical properties (e.g., TOC, bulk density), and total PCB concentrations;
- Whole Lower Fox River Model (wLFRM) used to simulate the movement of PCBs in the water column and sediment of the Lower Fox River from Little Lake Butte des Morts to the mouth of the River at Green Bay;
- Fox River Food Chain Model (FRFood) used to simulate the uptake and accumulation of PCBs in the aquatic food chain in the Lower Fox River based on the model results from wLFRM;
- Enhanced Green Bay PCB Transport Model (GBTOXe) used to simulate the movement of PCBs in the water column and sediment of Green Bay from the mouth of the Lower Fox River to Lake Michigan, including loading rates to Green Bay based on model results from wLFRM; and
- Green Bay Food Chain Model (GBFood) used to simulate the uptake and accumulation of PCBs in the aquatic food chain in the lowest reach of the Lower Fox River and in Green Bay.

These computer models were used to project changes in total PCBs in water, sediment, and fish over time. These models are mathematical representations of transport and transfer of PCBs between the sediments, water, and uptake into the food webs described in Section 3 of the FS.

The relationship between the models, their projected output, and how the output is used in evaluating risks, is described in the MDR. The bed maps produced as part of the RI are the foundation of the modeling inputs. The surface sediment total PCB concentrations for the baseline and action levels discussed in Section 5 of the FS are used as the inputs to both hydrodynamic models: the wLFRM and GBTOXe. These two models project total PCB concentrations in water and sediment. The output from the two transport models are used by the bioaccumulation models: FRFood and GBFood to project whole fish tissue concentrations of PCBs. The output from all of the models is then compared to the RALs specified in the FS.

Together, these models provided a method for evaluating the long-term effect on PCB concentrations in water, sediment, and aquatic biota under different remedial alternatives in the Lower Fox River and Green Bay. Alternatives were based on the removal of PCB-contaminated sediment above different action levels. By changing the initial PCB concentration in sediment such that all remaining sediments are below an action level, the models were then used to predict PCB concentrations in the aquatic environment over the next 100 years. The model results and conclusions from the model effort are discussed in the FS.

The MDR also describes how WDNR responded to issues raised through a model peer review conducted by the AGI. The panel prepared a report, which included a number of comments on the existing Lower Fox River models and recommendations for improving the model frameworks and conducting more robust and defensible modeling efforts. WDNR modified its model development effort to address many of the AGI concerns and modifications were made in response to many of the comments.

To complete the documentation, attached to the MDR are the complete set of finalized technical memoranda, the full detailed model documentation reports and user manuals, and a CD-ROM containing a working copy of each model, along with the input and output files for each model run. The Agencies believe that the model process is more than adequately documented. The Agencies also note that no other model offered for the Lower Fox River or Green Bay has a similar level of documentation.

## Master Comment 6.2

Commenters stated that the remedy in the Proposed Plan relied on *Technical Memorandum 2g* (TM2g) of the MDR to describe sediment bed elevation and scour throughout the site; when in fact, that document relies almost entirely on data from OU 4. The commenters state that more recently collected data from OU 1 suggest that the area is depositional and that natural attenuation is occurring.

## Response

WDNR and EPA agree that some statements concerning suspension and scour of sediments throughout the River may be too general and not as valid for Little Lake Butte des Morts as for the lower segments of the River. For example, Section 5.3 of the Proposed Plan, was written as an attempt to summarize the hydrodynamic characteristics of the Lower Fox River, with its principal point being that the sediments, in general, are dynamic and do not function in discrete layers. Discussion of the work of TM2g was included to add credence to the generalized statement that "scouring of the sediment bed plays a significant role in the quantity of sediment and contaminants transported through the river system." To avoid confusion, any future use of this information will clarify the locational specifics of the TM2g study.

However, the Agencies do not agree that that OU 1 is a "stable environment." While hydrographic surveys have not been performed in Little Lake Butte des Morts in recent years, site-specific data and other evidence of the dynamic nature of sediment bed conditions in OU 1 exist. In a recent study of short-term sediment deposition and resuspension in the Lower Fox River, Fitzgerald et al. (2001) collected Beryllium-7 (Be-7) samples from Deposit A in OU 1 and found that short-term sediment transport rates were up to 130 times larger than long-term net burial rates computed from Cesium-137 (Cs-137). Those authors conclude that the large difference between short-term and long-term accumulation rates in the Lower Fox River (including OU 1) suggests an extremely dynamic environment, even within an impounded river system.

Additional information also suggests that OU 1 is a dynamic environment. Estimated sediment trap efficiencies for this reach are approximately 10 percent, corresponding to long-term net burial rates of roughly 0.3 cm/yr, as reported in the wLFRM report in the MDR. Further, PCB concentrations in sediment samples recently collected from OU 1 include surface values much larger than previously reported for this reach, exceeding 360 ppm. Finally, the slow nature of net burial and the dynamic nature of sediment transport in OU 1 is demonstrated by the slow rate of natural recovery for this reach. More than 25 years after the virtual elimination of PCB discharges to OU 1, PCB concentrations in water and sediment remain at unacceptably high levels. This information is consistent with the findings reported by Fitzgerald et al. (2002) and suggests that rapid natural recovery is not occurring in OU 1.

Finally, citing the more recently collected data in OU 1 as "evidence" of the depositional nature of Little Lake Butte des Morts is not supported by a careful examination of the available information. *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples* shows that there has been very little change in PCB sediment concentration. The recent data show higher concentrations in Deposits A and POG than have previously been measured. When re-estimated using the newer data, the

SWAC was essentially equivalent to that calculated from earlier data. Regardless of the suggestion that there is an overall depositional nature of OU 1, there are areas where surface sediment concentrations have not decreased over the study period (Deposit A and portions of Deposit POG).

### Reference

Fitzgerald, S., J. Valklump, P.W. Swarzenski, R.A. MacKenzie, and K. D. Richards. 2001. Beryllium-7 as a Tracer of Short-Term Sediment Deposition and Resuspension in the Fox River, Wisconsin. Environ. Sci. Technol. 35:300-305

# 6.2 wLFRM

## 6.2.1 Adequacy of wLFRM

### Master Comment 6.3

Several commenters stated that the computer modeling supporting the RI/FS and Proposed Plan's analysis is flawed. Specifically citing the wLFRM, these commenters argued that the wLFRM: (1) does not appropriately track sediment PCB concentrations over the calibration period, (2) overstates the shear stress and amount of resuspension, (3) does not account for releases of PCBs during dredging, and (4) does not account for residual PCB concentrations post-dredging. Identifying these issues as "fundamental flaws," they argue the wLFRM cannot accurately predict future conditions and should not be used to make remedial decisions.

### *Response*

The commenters incorrectly imply that the wLFRM, or any model, was used solely to make remedial decisions. WDNR and EPA agree that no model can predict future conditions with a high degree of accuracy. As such, models were only one component of the remedial decision process, and were only used to help compare the relative differences between the various alternatives and action levels described in the FS.

*White Paper No. 9 – Remedial Decision-Making in the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, and Proposed Remedial Action Plan* describes how information from many different sources and supporting studies identified the need to implement an active remediation strategy for the Lower Fox River and Green Bay. No single source of information or study findings in and of itself leads to selection of a remedy. The combined findings of numerous supporting studies provides the clear weight of evidence that supports selection of the remedy. These findings and decision-making process are consistent with the three groupings of the EPA NCP nine CERCLA criteria as follows:

### Threshold Criteria

- Risks to human health and the ecosystem are unacceptable. Natural recovery has not effectively reduced risks in the 30-plus years timeframe since the cessation of the manufacturing and recycling of PCB-contaminated carbonless copy paper has ceased.
- WDNR and EPA objectives are to eliminate consumption advisories for recreational anglers within 10 years of completion of remediation and within 30 years for high-intake fish consumers.
- Natural dechlorination is not effective as a remedial alternative in the Lower Fox River. Dechlorination is limited to concentrations that are greater than 30 ppm, which exceeds the selected 1 ppm RAL.
- Natural attenuation, as evidenced by changes in sediment and fish tissue concentrations of PCBs over time, is not proceeding at a rate that would result in achievement of the Agencies' risk reduction goals.
- Comparative modeling shows that active remediation will result in risk reduction more quickly than either the MNR or no action alternatives and will achieve risk reduction objectives for certain fish species.
- This work can be completed while complying with ARARs of state and federal rules.

### Balancing Criteria

- There are large amounts of PCBs and contaminated sediment in the Lower Fox River. Much of this sediment is found in the top 100 cm of the sediment bed that can be managed by dredging.
- The sediment bed in the River is dynamic, resulting in resuspension and downstream transport of PCBs in the water column.
- Removal alternatives can achieve both short-term (e.g., remove to specific elevation or concentration, minimal resuspension of contaminated sediment) as well as long-term goals (e.g., removal of fish consumption advisories).
- An effective post-remediation monitoring program is needed to ensure and measure the effectiveness of any remedial action.

### Regulatory/Community Criteria

- WDNR and EPA have worked together on the selection of this remedy and both are in agreement with the selection for OUs 1 and 2.

- WDNR and EPA have taken many steps to inform the public of the work being conducted on the Lower Fox River and Green Bay and have used that input in preparing documents.

- Comments submitted by the public have been considered in the selection of this remedy for OUs 1 and 2. The responses to comments received during the public comment period are included in this RS.

With regards to the technical concerns raised by commenters, these are responded to in the Master Comments, below.

## 6.2.2 Calibration Issues

### Master Comment 6.4

Several commenters stated that the computer modeling supporting the RI/FS and Proposed Plan's analysis is inadequate for decision making. Specifically citing the wLFRM, these commenters argued that the wLFRM does not appropriately track sediment PCB concentrations over the calibration period. The commenters presented a figure that shows the forecasted sediment PCB concentrations over time for the Proposed Plan's natural attenuation or "No Action" scenario. Surface sediment PCB concentrations, they contend, are predicted to increase sharply during the first 5 years of the forecast, level off for 5 years, and then decline at a very slow rate. As a result of this surface sediment increase, they maintain that the wLFRM predicts that PCB surface concentrations will "bump up" and remain above current conditions for more than 40 years.

### *Response*

WDNR and EPA believe that the wLFRM is the appropriate transport model to use, in conjunction with the other tools cited in Master Comment 6.3. With respect to the ability of the wLFRM to appropriately track sediment PCB concentrations during the calibration period, *White Paper No. 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study and Proposed Remedial Action Plan* noted that simulated reach averaged surface sediment PCB levels in the wLFRM fall within, and never exceed, the 95 percent confidence intervals of observed PCB levels. Considering the area between the De Pere dam and the River mouth (OU 4), the upper 95 percent confidence limit of the observations is more than 60 percent larger than the average. Model results for OU 4 never exceed the 95 percent confidence limit of observed PCB levels for this reach. The small (~1 ppm) difference in model results over time is more a reflection of the spatial heterogeneity of the observations rather than any failure of the model to appropriately track surface sediment PCB levels.

It is also important to note that the commenter's concern regarding the ability of the model to track PCB levels is based on the incorrect premise that PCB concentrations in sediments can never increase over time. At any location where PCB levels immediately below the surface-most sediments exceed the PCB levels found in surface sediment, the possibility for PCB increases exists. Any time bed elevation decreases occur at that location, the average PCB concentration in the top 10 cm of sediments will increase. As demonstrated by TM2g (WDNR, 1999) and follow-up efforts, such decreases in sediment bed elevations are common in the Lower Fox River. Given that wLFRM performance falls within the 95 percent confidence limit of the observations and that sediment bed elevations decreases do occur and may cause PCB levels in surface sediments to increase, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

Further, it must be recognized that the main pathway for risk in the Lower Fox River is PCB exposure via the water column. As part of model calibration, both the water column and sediment bed were considered. Once model results for both the water column and sediment bed met the model performance criteria established in Technical Memorandum 1, the model calibration was considered acceptable. Despite the greater uncertainty of model results for the sediment column, model performance for sediment PCB levels is nonetheless acceptable. More importantly, model performance for the central risk pathway, water column PCB exposures, is quite good. Again, in light of all these factors, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

### Reference

WDNR, 1999. *Technical Memorandum 2g: Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations*. Wisconsin Department of Natural Resources, Madison, Wisconsin. July 23.

## Master Comment 6.5

Commenters argued that model's prediction of PCB sediment concentrations under the "no action" alternatives does not reflect the strong and continuing downward trend shown by actual sediment data. They contend that, as a result, the model underestimates the degree to which natural attenuation is taking place.

## *Response*

The claim that a strong and continuing downward trends in Lower Fox River sediment PCB levels exist is not supported by observations. Surface sediment PCB concentration trends were examined in two different supporting studies as part of the RI/FS. As documented by Appendix B of the MDR (the wLFRM report), there is no clear trend. At different locations, surface sediment PCB levels appear to increase, decrease, or stay the same. Similar findings were also reported by The Mountain-Whisper-Light Statistical Consulting (TMWL) (Appendix B of the RI). The wLFRM report in the MDR describes four conclusions that may be drawn from these data: (1) a spatial trend of generally decreasing sediment PCB concentration with distance from Lake Winnebago exists; (2) apparent PCB concentration changes over time may reflect the spatial heterogeneity of PCBs in the sediments; (3) at any individual location, sediment PCB concentrations may increase, decrease, or stay the same over time; and (4) the overall rate at which surface sediment PCB concentrations change over time is slow.

The Agencies further note that the commenters relied on inappropriate combinations of data to provide their analysis of “strong downward trends.” Over time, data were collected at different locations, from different strata, and using different sample collection and analytical protocols. In addition, post-GBMBS sampling efforts often had biased objectives as reflected in at least two data collection activities at Deposit A where the objective was to delineate the extreme edges of the deposit. Biases introduced as a result of these methodological differences are more than large enough to account for any trends the commenters inferred. A brief discussion of these biases is provided by in the MDR (Appendix A).

## 6.2.3 Sediment Bed Dynamics in OU 1 versus OU 4

### Master Comment 6.6

Commenters claimed that the FS and Proposed Plan rely on studies of sediment bed dynamics in OU 4, and not OU 1 was cited by some commenters as a deficiency in those documents. The commenters argue that site-specific data indicate that Little Lake Butte des Morts’ sediment bed is stable, not dynamic as suggested TM2g. The MDR and the Proposed Plan chose not to include or discuss TM5d, and chose to represent Little Lake Butte des Morts as a dynamic system.

### *Response*

Like all supporting studies, the results of TM5d were considered during development of the wLFRM, as well as the RI/FS and Proposed Plan. Note that TM5d was a modeling study of sediment transport in Reaches 1 through 3 of the River. As part of TM5d development, numerous assumptions were made regarding the nature and grain size distribution of solids entering the River from Lake Winnebago. As noted in Appendix A of the MDR, TM5d and wLFRM results are sensitive to the grain size distribution of the upstream boundary condition and that the uncertainty associated with the grain size distribution of the upstream solids boundary condition is significant. Further discussion of this point is provided in Section 3.5.1 of Appendix A of the MDR.

As discussed in Master Comment 6.2, site-specific data and other evidence of the dynamic nature of sediment bed conditions in OU 1 exists. In a recent study of short-term sediment deposition and resuspension in the Lower Fox River, Fitzgerald et al. (2001) concluded that the large difference between short-term and long-term accumulation rates in the Lower Fox River (including OU 1) suggests an extremely dynamic environment, even within an impounded river system.

Additional information also suggests that OU 1 is a dynamic environment. Estimated sediment trap efficiencies for this reach are approximately 10 percent, corresponding to long-term net burial rates of roughly 0.3 cm/yr. Further, PCB concentrations in sediment samples recently collected from OU 1 include surface values much larger than previously reported for this reach; as high as 360 ppm. Finally, the slow nature of net burial and the dynamic nature of sediment transport in OU 1 is demonstrated by the slow rate of natural recovery for this reach. More than 25 years after the elimination of PCB discharges to OU 1, PCB concentrations in water and sediment remain at unacceptably high levels. This information is consistent with the findings reported by Fitzgerald et al. (2001) and suggests that rapid natural recovery is not occurring in OU 1.

Given the recent findings of very high surface sediment PCB concentrations in OU 1 as well as the site-specific findings of Fitzgerald et al. (2001), WDNR and EPA believe the claim that the sediment bed of OU 1 is uniformly and consistently stable are unfounded.

### Reference

Fitzgerald, S. A., J. Val Klump, P. W. Swarzenski, R. A. Mackenzie, and K. D. Richards, 2001. Beryllium-7 as a tracer of short-term sediment deposition and resuspension in the Fox River, Wisconsin. United States Geological Survey. *Environmental Science & Technology*. 35:300–305.

## Master Comment 6.7

Commenters stated that the wLFRM predicts steady erosion in roughly 20 sediment bed segments in the center navigation channel of the River below the De Pere dam. For decades, it has been necessary for the USACE to dredge this navigation channel to keep the channel open for commercial traffic. Thus, they conclude that many of the specific areas that wLFRM assumes to be erosional are the same areas the USACE must dredge regularly to remove new deposits.

**Reference**

Fitzgerald, S., J. Valklump, P.W. Swarzenski, R.A. MacKenzie, and K. D. Richards. 2001. Beryllium-7 as a Tracer of Short-Term Sediment Deposition and Resuspension in the Fox River, Wisconsin. Environ. Sci. Technol. 35:300-305

### *Response*

WDNR and EPA disagree with this comment. While observed bed elevations are more dynamic than wLFRM results (or the results of any sediment transport model developed for the site), the model typically represents the direction of bed elevations changes over time as shown in Table 4-5 of the wLFRM report in the MDR.

However, it is important to note that this comment misrepresents the extent of dredging and locations where dredging has occurred in the Lower Fox River over the past 30 years. The only areas where dredging has routinely occurred are the Fort James (Georgia Pacific) and East River turning basins. As documented in TM2g, much of the navigation channel has not been dredged in 30 years. Of those few locations where dredging has occurred, many of those areas have been dredged once. The reason that dredging has not occurred in much of the navigation channel is because sediment bed elevations have either been relatively constant or have decreased over time.

Given that dredging in the navigation channel has been quite limited over the past 30 years, that bed elevations in some areas of the navigation channel have decreases over time, and the ability of the model to represent the direction of bed elevation changes over time, WDNR and EPA believe this comment is unfounded.

## 6.2.4 ECOM-SED/Technical Memorandum 5d versus Technical Memorandum 2g

### Master Comment 6.8

The shear stress and depth of scour used by wLFRM was questioned by some commenters. They argued that the ECOM-SED model and the RMA model predict substantially lower shear stress and depth of scour near the banks of the River.

### *Response*

This comment overstates the differences between hydrodynamic model results and conditions in the wLFRM. The wLFRM uses flow-velocity relationships developed from the results of hydrodynamics models to estimate shear stresses and erosional amounts (from which depth of scour is estimated).

These flow-velocity relationships relate average hydrodynamic velocities over the surface area of each sediment deposit, interdeposit area, and sediment management unit (SMU) to the average flow. The average value used in the wLFRM will represent the average hydrodynamic value that occurs over any sediment area. It is therefore important to recognize that the hydrodynamic models and the wLFRM have different spatial scales. Within any wLFRM segment, hydrodynamic model results can be somewhat larger or smaller than the average value. However, when hydrodynamic model grid cells within a given wLFRM segment are appropriately averaged, there is a direct correspondence between the hydrodynamic model results and the wLFRM.

To make long-term simulations computationally feasible, the wLFRM was developed with a coarser spatial scale than ECOM-SED. ECOM-SED grid cells are much smaller (~60 meters by 90 meters) than those needed to develop the wLFRM (~400 meters by 1,000 meters). ECOM-SED results were averaged over wLFRM water column segments to produce a relationship between velocity and average flow. Averaging is also necessary because: (1) flow is the only parameter for which a long-term record exists from which velocity can be estimated; and (2) the long-term flow observations (1954–1995) include conditions which did not occur during the ECOM-SED (TM5b, TM5c) 1989–1995 calibration period. As a result of spatial averaging, some fine-scale detail is lost. However, average velocities are preserved. By definition of an average quantity, for each case where the velocities at individual ECOM-SED grid cells are less than the average velocity of a wLFRM segment, there are an equal number of locations where velocities at ECOM-SED grid cells exceed the wLFRM average velocity. Perhaps more importantly, it is worth noting that the purpose of the wLFRM was to provide insight into the relative trends and magnitudes of PCB concentrations over time on a reach-by-reach basis. For this spatial (and temporal) scale, use of average velocity values is very reasonable. Proposed remedial strategies are provided on a reach-by-reach basis. Management of contaminated areas on a 60-meter by 90-meter scale is impracticable. Even if remediation on such a fine scale were practicable, preservation of ECOM-SED (or RMA) results at the full spatial (and temporal) resolution of the two-dimensional hydrodynamic model is of questionable value. The flow structure of a natural system is three-dimensional as secondary and helicoidal flows and other conditions occur. Vertically averaged, two-dimensional hydrodynamics models do not resolve such flow features (see Lane et al., 1999). Under such conditions, retaining the full precision of a two-dimensional hydrodynamic approximation provides no additional accuracy. In essence, representing an approximation with more significant figures does not improve the accuracy of the approximation.

**Reference**

Lane, S.N., K.F. Bradbrook, K.S. Richards, P.A. Biron, A.G. Roy. 1999. The application of computational fluid dynamics to natural river channels: three-dimensional versus two-dimensional approaches. Geomorphology 29: 1–20

## 6.2.5 Depth of Mixing

### Master Comment 6.9

Commenters stated that the wLFRM improperly uses a mixing depth of 30 cm, and should instead use a 10-cm mixing depth.  They further maintain that the draft MDR dated October 2001 does not provide any justification for the assumption of a 30-cm mixing depth and argue that the literature “standard” for mixing is 10 cm.

### *Response*

Mixing depths used in the wLFRM are well supported by field data. Observed sediment mixing depths vary widely. While typical mixing depths range from 10 to 30 cm, sediment disturbances of up to 200 cm have been observed. It should be noted that this comment asserts that a “standard” sediment mixing depth exists. This assertion is based on the incorrect premise that mixing is almost exclusively driven by biological processes and other processes do not disturb the sediment bed. However, contrary to this premise, other processes such as bed elevation changes due to flow events, density currents, methane flux, and sediment slumping can also disturb and mix sediments.

As described in TM2g and follow-up efforts (WDNR, 2001), sediment bed elevations in the Lower Fox River are very dynamic. Over monthly to annual times scales, sediment bed elevations have been observed to regularly fluctuate between 10 to 30 cm. Larger fluctuations of approximately 200 cm have also been recorded over annual time scales. Over broad areas, the net change in bed elevation is very small. This means that at each location where a large decrease in bed elevation occurs, there is typically a nearby location with a correspondingly large increase in elevation. Consequently, within the same general area there is a pattern of mixing where particles and contaminants located deeper within the sediment column can return to the sediment surface and materials initially at the surface are buried until the next disturbance occurs.

In addition to bed elevation data, the periodic disturbance of sediments to considerable depth in the sediment column is supported by the Cesium-137 (Cs-137) profile results reported by Steuer et al. (1995) that show sediment disturbances to depths of approximately 40 cm. It should also be noted that data provided by the comment documents mixing depths of up to 20 cm from locations where intact Cs-137 profiles could be obtained. Given the large number of observations that indicate sediment mixing depths are variable and that sediment disturbances of up 200 cm can occur, WDNR and EPA believe the claim that sediment mixing depths are limited to 10 cm is not defensible.

### References

Steuer, J., S. Jaeger, and D. Patterson, 1995. *A Deterministic PCB Transport Model for the Lower Fox River Between Lake Winnebago and De Pere, Wisconsin*. Wisconsin Department of Natural Resources Green Bay and Madison, Wisconsin. 283 p.

WDNR, 2001. *Development and Application of a PCB Transport Model for the Lower Fox River*. Wisconsin Department of Natural Resources, Madison, Wisconsin. June 15.

## Master Comment 6.10

Commenters stated that the wLFRM's segmentation of the sediment bed is flawed because initial segment thicknesses in the model vary from 5 cm at the surface to 50 cm at depth. As a result, the mixed depth of sediment increases significantly over time in some areas, exacerbating the effects of the 30-cm mixing depth error described above. They further argue that these uneven strata make the wLFRM incapable of accurately reflecting surface sediment concentrations when erosion occurs.

## *Response*

The depth to which sediment mixing or other disturbances may occur is not constant and varies widely by location and over time. This is described in detail in Appendix A of the MDR. The most straightforward method to represent variability in the depths of sediment disturbances was the use of sediment segments that increase in thickness with depth below the sediment-water interface. By use of this segmentation approach, the sediment mixing depth in and sediment stack can vary in response to the extent of erosion or deposition that occurred. Areas subject to larger disturbances will take on a larger mixing depth and areas subject to less extensive disturbances will take on a smaller mixing depth. Given the observed extent and variability of sediment mixing depths as summarized in Appendix A of the MDR, in *White Paper 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision*, and LTI (2002), WDNR and EPA believe that mixing depths are appropriately represented in the wLFRM.

### Reference

LTI, 2002. Measurement of Burial Rates and Mixing Depths Using High Resolution Radioisotope Cores in the Lower Fox River. In: *Comments of the Fox River Group on the Wisconsin Department of Natural Resources' Draft Remedial Investigation, Draft Feasibility Study, Baseline Human Health and Ecological Risk Assessment, and Proposed Remedial Action Plan*. Appendix 10. Prepared by Limno-Tech, Inc., Ann Arbor, Michigan.

## Master Comment 6.11

Commenters argued that application of the wLFRM results in an artificial buildup of PCB mass in the surface sediment layers.

## *Response*

WDNR and EPA believe the commenters have misrepresented the nature of wLFRM results. With respect to the ability of the wLFRM to appropriately track sediment PCB concentrations during the calibration period, note that simulated reach averaged surface sediment PCB levels in the wLFRM fall within, and never exceed, the 95 percent confidence intervals of observed PCB levels. Considering the area between the De Pere dam and the River mouth (Reach 4), the upper 95 percent confidence limit of the observations is more than 60 percent larger than the average as previously noted. Model results for Reach 4 never exceed the 95 percent confidence limit of observed PCB levels for this reach. The small (~1 ppm) difference in model results over time, described as an "artificial buildup" by the commenters, is more a reflection of the spatial heterogeneity of the observations rather than any failure of the model to appropriately track surface sediment PCB levels. Because model results never fall outside this confidence limits of the initial condition, the proper interpretation of wLFRM results is that the model predicts little change in surface sediment PCB levels over time. Such a result and interpretation is consistent with the surface sediment PCB trends analyses presented in the RI/FS.

Perhaps more significantly, note that this comment regarding the ability of the a model to track PCB levels is based on the flawed premise that PCB levels in sediments can never increase over time. In contrast to this premise, not that at any location where PCB levels immediately below the surface-most sediments exceed the PCB levels found in surface sediment, the possibility for PCB increases exists. Any time bed elevation decreases occur at that location, the average PCB concentration in the top 10 cm of sediments will increase. As conclusively demonstrated by TM2g (WDNR, 1999) and follow-up efforts, such decreases in sediment bed elevations are common in the Lower Fox River. Given that wLFRM performance falls within the 95 percent confidence limit of the observations and that sediment bed elevations decreases do occur and may cause PCB levels in surface sediments to increase, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

Further, it must again be recognized that the main pathway for risk in the Lower Fox River is PCB exposure via the water column. As part of model calibration, both the water column and sediment bed were considered. Once model results for both the water column and sediment bed met the model performance criteria established in Technical Memorandum 1 (LTI and WDNR, 1998), the model calibration was considered acceptable. Despite the greater uncertainty of model results for the sediment column, model performance for sediment PCB levels is nonetheless acceptable. More importantly, model performance for the central risk pathway, water column PCB exposures, is quite good. Again, in light of all these factors, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

### References

LTI and WDNR, *1998. Technical Memorandum 1: Model Evaluation Metrics*. Limno-Tech Inc., Ann Arbor, Michigan and Wisconsin Department of Natural Resources, Madison, Wisconsin. March 13.

WDNR, 1999. *Technical Memorandum 2g: Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations*. Wisconsin Department of Natural Resources, Madison, Wisconsin. July 23.

## Master Comment 6.12

Commenters stated that the wLFRM does not adequately represent the relationship between sediment volumes and exchange areas in subsurface sediment layers.  They content that this leads to greater rates of erosion in some areas.

## *Response*

This comment is mischaracterizes the operation of the IPX 2.7.4 modeling framework and the performance of the wLFRM. Surface areas for all sediment layers in the wLFRM vary as determined from field data. As erosion and deposition occur during a simulation, the IPX 2.7.4 framework always uses the appropriate surface area of the sediment segment to compute the mass flux of material to or from each sediment segment. The IPX 2.7.4 framework appropriately manages sediment surface areas (and all other properties) regardless of whether erosion or deposition occurs in a segment. Management of sediment stack properties within IPX 2.7.4 is performed in Subroutines PUSH and POP. Sections 1.5.3.2 and 1.5.4.2 of the IPX 2.7.4 user’s manual (EPA, 2001) describe the operation of these subroutines. Further, examination of model source code for these two subroutines shows that sediment properties are appropriately managed. Therefore, comments that purport that the relationships between sediment segment volumes and surface areas are not properly represented in the wLFRM are not accurate.

**Reference**

EPA, 2001. *A User's Guide to IPX, the In-Place Pollutant Export Water Quality Modeling Framework, Version 2.7.4*. EPA/600/R-01/079. United States Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division, Large Lakes Research Station, Grosse Ile, Michigan. 179 p.

## 6.2.6 Water Column/Pore Water

### Master Comment 6.13

One commenter stated that the wLFRM does not include any modeling process to account for pore water diffusion.

### *Response*

Porewater diffusion is one of the possible mass transfer pathways for PCBs in the sediments. This process is included in the conceptual model framework, and is discussed in *White Paper 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision*. Porewater transfers can move dissolved PCBs between sediment layers and to the water column. In the wLFRM, PCB porewater transfer functions were specified between layers in the sediment column. However, due to an oversight when the model input data files were constructed, the final linkage between the surface sediments and the water column was not specified. Note that porewater diffusion can only transport dissolved and bound phase PCBs. Also note that PCBs are strongly associated with particles because they are hydrophobic and that less than 1 percent of the PCBs in the sediments are expected to be associated with dissolved and bound phases. As a result, the impact of this oversight is expected to be very small.

## 6.2.7 Dredging Releases/Residuals

### Master Comment 6.14

Commenters argued that the wLFRM should have accounted for dredging processes, including PCB remobilization during dredging, and residual PCB concentrations post-dredging. They note that the wLFRM modeling analysis did not include any PCB releases to the water column from dredging, which they contend results in overestimating removal relative to Monitored Natural

Recovery. In addition, they maintain that wLFRM should have explicitly accounted for post-dredging PCB sediment concentrations.

### Response

Direct releases of PCBs can occur during dredging active operations. Such direct releases of PCBs were not explicitly included in the site-specific chemical transport and bioaccumulation models developed for the RI/FS. This model design factor was based on consideration of the scale of annual PCB mass transport through the River and the ability to control potential releases during dredging.

With respect to the representation of PCB releases during dredging, note the wLFRM represents remediation by a series of alternative-specific targets for post-remediation sediment bed elevations and PCB concentrations initially at depth in the sediment bed. The wLFRM does not explicitly simulate dredging. As discussed in *White Paper 9 – Remedial Decision-Making for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision*, PCB releases during dredging are expected to be very small relative to existing levels of PCB transport in the Lower Fox River. In particular, it should be noted that during the Deposit N and SMU 56/57 demonstration projects, the mass of PCBs released by dredging was roughly two orders of magnitude smaller (less than 1 percent) than the present level of ongoing PCB transport through the Lower Fox River. Assuming full-scale dredging operations were initiated, direct releases of PCBs during dredging (a few kilograms per year) would always be far smaller than natural transport rates (several hundred kilograms per year). Further, as documented by the *Sediment Technologies* supporting study of the RI/FS, direct PCB releases during dredging can be minimized by the use of careful controls during dredging. Given these observations, the effect of PCB releases during dredging and the impact of PCBs potentially present in post-dredge patina layers were considered negligible.

As for the incorporation of dredging releases into the water quality modeling, WDNR and EPA see little value in adding another variable into the models. Any differences between model results with or without the 2.2 percent dredging losses observed at SMU 56/57 are well within the uncertainty of the models, given that the acceptable threshold for model performance developed in cooperation with the FRG (*Model Evaluation Workgroup Technical Memorandum 1: Model Evaluation Metrics*). The acceptable level of performance defined in Technical Memorandum 1 is ±30 percent of observed concentrations.

With respect to the representation of residual surface sediment PCB concentrations immediately following dredging, note the wLFRM represents remediation by a series of alternative-specific targets for post-remediation sediment bed elevations and PCB concentrations. Patinas (thin residual layers) of more-highly PCB-contaminated sediments were not explicitly included in the wLFRM based on consideration of the ability of dredging technologies to achieve low residual PCB concentrations and the rapid rate at which conditions at the sediment-water interface are expected to change following dredging. In particular, as monitored following first phase of the SMU 56/57 demonstration project in 1999, PCB concentrations in portions of the dredged area where post-dredging bed elevation meet the target elevation were approximately equal to PCB concentrations initially present at that sediment depth (WDNR, 2000b). Further, post-dredging monitoring of the SMU 56/57 site showed that rapid changes in the sediment-water interface occurred over time and that conditions a few months following dredging did not resemble conditions immediately following dredging (WDNR, 2002a). Given these observations, the effect of PCB releases during dredging and the impact of PCBs potentially present in post-dredge patina layers were considered negligible.

### References

WDNR, 2000a. *Addendum to Technical Memorandum 2e: Estimation of Sediment Bed Properties for the Lower Fox River (4 reach effort).* Memorandum prepared by G. Fritz Statz. Wisconsin Department of Natural Resources, Madison, Wisconsin. October 26.

WDNR, 2000b. *Post-Dredging Results for SMU 56/57*. Memorandum prepared by Bob Paulson. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 21.

# 6.3 FRFood

## Master Comment 6.15

Commenters stated that the food web model used for the Lower Fox River (FRFood) does not accurately represent the bioaccumulation processes operating in the Lower Fox River. They state that FRFood was constructed using model parameters taken exclusively from scientific literature, with no attempt to determine whether those parameters were appropriate for the Lower Fox River system. They question the use of fillet to whole body ratios in the model development. As a result, they maintain that FRFood contains assumptions that are inconsistent with actual data collected from the Lower Fox River, and will not accurately predict the impact of remedial alternatives on fish tissue PCB concentrations in the Lower Fox River.

## *Response*

WDNR and EPA disagree with comments implying that the FRFood model contains significant errors and/or incorrect parameterizations. This comment is based upon the review conducted on behalf of the FRG by Limno-Tech, Inc. (LTI), in an attachment to the FRG comments entitled *Evaluation of WDNR Fate and Transport and Food Web Models for the Lower Fox River/Green Bay System*. Issues relating to adequacy of the model, documentation, calibration, and growth rates are discussed below.

### Adequacy of the Gobas Model

FRFood was based upon the algorithms developed originally by Gobas (1993). The Agencies believe that the robustness of the model and its applicability to the Lower Fox River is demonstrated by the successful use at other sites, including:

- The model was developed for Great Lakes food chains and has been previously validated using both Lake Ontario and Green Bay PCB and food web data.
- EPA made extensive use of the Gobas model to derive bioaccumulation factors, bioconcentration factors, and food chain multipliers in the development of the Great Lakes Water Quality Initiative (GLWQI) criteria (EPA, 1993, 1994).
- The Gobas model was used in the 1996 RI/FS for the Lower Fox River and found to yield reasonably good results between predicted and measured fish tissue PCB concentrations (GAS/SAIC, 1996).
- A modified version of the Gobas model was used for the Ecological Risk Assessment for the Sheboygan River, Wisconsin, and also found reasonable similarity between predicted and measured PCB levels in fish (EVS, 1998).
- The Gobas algorithms, as developed into the FISHRAND model, were used to project future PCB concentrations in fish for the Hudson River (EPA, 2000).

In fact, the Agencies note that most of the comments raised in the LTI report were the same as those raised, but successfully defended, for FISHRAND on the Hudson River.

### FRFood Model Documentation

The Agencies believe that the underlying algorithm developed originally by Gobas (1993) are sufficiently robust to support the FS, and that documentation provided is more than adequate to have reconstructed the parameterization. The complaint that there was inadequate documentation to the model itself is inaccurate. Model algorithms were described in the *FRFood Model Documentation Memorandum* in as far as changes or modifications to the original Gobas (1993) were added to the version of FRFood that was developed in MS Access format. These are defined in Section 2 of the *FRFood Model Documentation Memorandum*. Furthermore, the entire FRFood model, along with all of the model runs conducted for the FS was provided on a CD-ROM. All of the information necessary to fully evaluate the model was provided to the public.

### Calibration

Output from the FRFood model matched up very tightly with the observed fish tissue concentrations, both within the calibration period of 1989–1995, but also when projected out to the data collected in 1998. Both point projections, as well as projections by FRFood when coupled with the output from wLFRM were found to have excellent agreement with the observed data, contrary to the statements made by LTI.

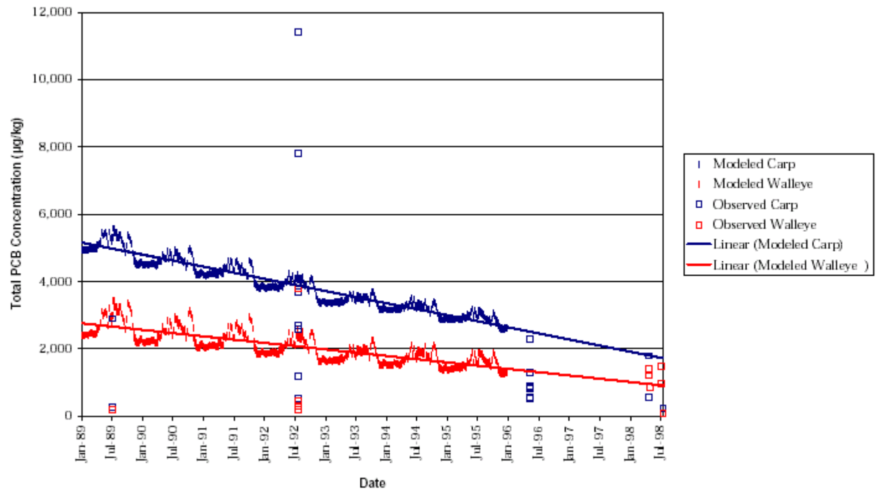
A discussion of the FRFood model calibration was provided in the documentation, and in Section 7 of the BLRA. As described fully in that document, FRFood was first calibrated based upon point estimates; measured sediment and water concentrations within each reach were used as a basis for estimating fish tissue concentrations for multiple species. The model was parameterized for each reach and its specific food web, and calibration continued until model predictions matched measured fish tissue concentrations.

FRFood was then checked against the output from wLFRM, and from GBTOXe, and predicted concentrations for most of the fish species. For OUs 1 and 4, the combined FRFood/wLFRM output shows very good agreement with the observed data. As noted in the FRFood document, there is excellent correlation, especially for carp and walleye in OUs 1 and 4. Figures 3-3 and 3-5 from the memorandum are shown below (Figures 5 and 6). For example, in OU 4 the projected values were within 86 and 96 percent of the observed values, respectively, for those two species over the calibration period. When projected out to fish tissue concentrations observed in 1998, the wLFRM/FRFood projections were well within the observed data.

# Figure 5 FRFood Calibration: Little Lake Butte des Morts

*Fox River Food (FRFood) Model Documentation Memorandum*

**Figure 3-3 FRFood Calibration: Little Lake Butte des Morts**
**Predicted vs. Observed Total PCBs in Walleye and Carp**
**1989–1998**

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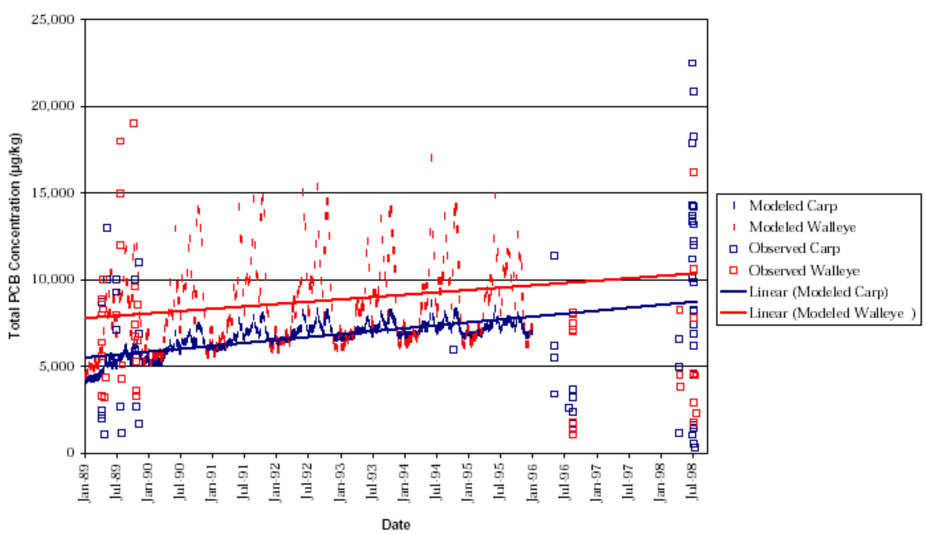
# Figure 6 FRFood Calibration: De Pere to Green Bay Reach

*Fox River Food (FRFood) Model Documentation Memorandum*

**Figure 3-5 FRFood Calibration: De Pere to Green Bay Reach**
**Predicted vs. Observed Total PCBs in Walleye and Carp**
**1989–1998**

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Concerning the topic of fillet to whole body ratios. These were used to develop the SQTs for human health, and are discussed in Section 4. The ratios were not used in the calibration; their inclusion as a table in Section 3 is a minor error readily realized by reading the text.

Concerning whether graphics were "improperly" labeled; the commenter complained that they could not determine what the units were in graphics or tables. In all cases, as recorded in the text, units are displayed and report PCB concentrations based upon the wet weight of this fish.

### Food Web and Prey Preference

The Agencies believe that the food web and prey preferences developed for FRFood are good representations of the bioaccumulation pathways in the Lower Fox River and Green Bay. The food web and prey preferences were developed in FRFood based upon site-specific information, and knowledge of similar species diets gained from scientific literature. Food web and prey preferences are documented in both *Technical Memorandum 7b* (Exponent, 1999) and *Technical Memorandum 7c* (TM7c) (WDNR, 2001). Both of those documents rely, in part, on the content analyses conducted by Magnuson and Smith (1987). Even the FRG's consultant noted that, "Site-specific stomach content data provide a solid foundation for determining predator diets in the Connolly et al. (1992) food web model" (Exponent, 1999). The food web, diets, and proportion of diets were developed and evaluated with WDNR fisheries biologists who have worked with the species of interest for several years.

### Growth Rate

Commenters stated that the growth rate used in FRFood was not appropriate for application to the Lower Fox River, and that the appropriate growth rate should be at least an order of magnitude lower than that applied. One argument was that the growth rate used would result in PCB concentrations too high from observed values.

The growth rate constant used in FRFood was 0.002, which was obtained from the original Gobas model. This value is appropriate given the value was developed for Lake Ontario for similar species and conditions found in the Lower Fox River. Growth rate, within the Gobas framework, used a constant to account for dilution of PCB concentration due to growth. Intuitively, arguing for a lower growth rate (0.0002 as the commenter suggests) would result in less dilution. As a sensitivity check, FRFood was run using parameters for OU 1, with growth rates set at one order of magnitude above and below the growth rate used for the FS. As can be seen in the table below, using a growth rate one order of magnitude below results in an increase in PCB wet weight (ww) concentrations in fish. Increasing the growth rate results in a lower concentration of PCBs.

| | | | |
|---|---|---|---|
| Growth Rate | 0.0002 | **0.002** | 0.02 |
| Sediment (mg/kg) | 3.8 | **3.8** | 3.8 |
| Carp – Adult (mg/kg ww) | 4,560 | **2,639** | 506 |
| Carp – YOY | 2,859 | **1,607** | 299 |
| Dissolved in Water | 0 | **0** | 0 |
| Emerald Shiner (mg/kg ww) | 1,610 | **868** | 155 |
| Gizzard Shad (mg/kg ww) | 1,220 | **358** | 44 |
| Oligochaetes | 268 | **268** | 268 |
| Phytoplankton | 27 | **27** | 27 |
| Total in Water | 0 | **0** | 0 |
| Walleye – Adult (mg/kg ww) | 6,146 | **2,109** | 207 |
| Walleye – YOY | 6,132 | **2,091** | 157 |
| Yellow Perch – Adult (mg/kg ww) | 2,169 | **1,443** | 332 |

## References

Connolly, J. P., T. F. Parkerton, J. D. Quadrini, S. T. Taylor and A. J. Thuman, 1992. *Development and Application of a Model of PCBs in the Green Bay, Lake Michigan Walleye and Brown Trout and Their Food Webs*. Report to the United States Environmental Protection Agency, Grosse Ile, Michigan. Cooperative Agreement CR-815396.

EPA, 1993. Updated version of the Region 8 CWA Section 304(a) criteria chart. United States Environmental Protection Agency.

EPA, 1994. *Estimating Exposure to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence and Background Exposures*. Review Draft (do not cite or quote). EPA/600/6-88-005Cb. United States Environmental Protection Agency, Washington, D.C.

EPA, 2000. *Responsiveness Summary – Hudson River PCBs Site Record of Decision*. Prepared for United States Environmental Protection Agency, Region 2 and United States Army Corps of Engineers, Kansas City District by TAMS Consultants, Inc. January.

EVS, 1998. *Sheboyan River and Harbor Aquatic Ecological Risk Assessment (Volume 1 of 3), Seattle, Washington*. Prepared by EVS Environment Consultants and National Oceanic and Atmospheric Administration.

Exponent, 1999. *Technical Memorandum 7a: Analysis of Bioaccumulation in the Fox River*. Prepared for the Fox River Group and the Wisconsin Department of Natural Resources by Exponent, Bellevue, Washington. February.

GAS/SAIC, 1996. *Remedial Investigation Report for Contaminated Sediment Deposits on the Fox River (Little Lake butte des Morts to the De Pere Dam)*. Graef, Anhalt, Schloemer & Associates (GRAEF) and Science Applications International Corporation (SAIC). September 24.

Gobas, F. A. P. C., 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food webs: Application to Lake Ontario. *Ecological Monitoring*. 69:1–17. December 8.

Magnuson, J. J. and D. L. Smith, 1987. *Food Chain Modeling Needs Obtained Through Stomach Analysis of Walleye and Brown Trout*. Final Report to United States Environmental Protection Agency. University of Wisconsin.

WDNR, 2001. *Technical Memorandum 7c: Recommended Approach for a Food Web/Bioaccumulation Assessment of the Lower Fox River/Green Bay Ecosystem*. Wisconsin Department of Natural Resources. January.

## Master Comment 6.16

Commenters stated that FRFood contained errors and other limitations that caused FRFood to generate predictions which conflict with known data from the River.

## *Response*

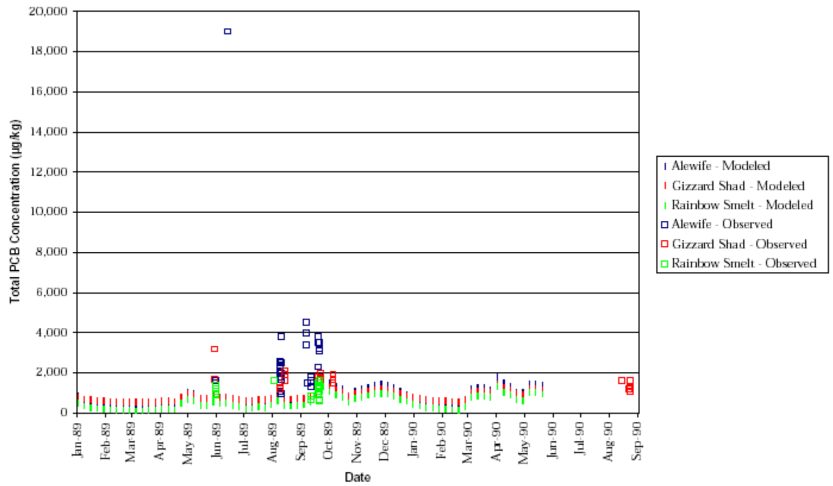
The WDNR and EPA disagree with this statement. As noted in the previous comment, both point and wLFRM/GBTOXe-coupled predictions matched very well with measured fish tissue concentrations in the Lower Fox River and Green Bay Zone 2, and readily met the model evaluation metrics developed in the GBMBS and agreed upon by the WDNR in cooperation with the FRG (Limno-Tech, 1998). As described in Technical Memorandum 1 of the *Model Documentation Report*, the metric applied to bioaccumulation models is plus or minus one-half order of magnitude**.** Given that results of FRFood from either point or coupled calibration with the transport models was within 0.6 to 2.2 times observed values, the model fits well within the FRG agreed-to model metric.

Both during the calibration period, and when using a straight-line projection from the calibration period to the most recent data collected in 1998, the coupled transport/FRFood model provided a good projection that matches well with the observed fish tissue concentrations. Figures 3-3, 3-5 (see Figures 5 and 6 above), 3-6, and 3-7 (Figures 7 and 8 below) from the *FRFood Model Documentation Memorandum* show that for OUs 1 and 4, and Green Bay Zone 2, FRFood model projections accurately represent observed fish tissue concentrations; both within the calibration period and projected into 1998.

## Figure 7 FRFood Calibration: Green Bay Zone 2, Forage Fish

*Fox River Food (FRFood) Model Documentation Memorandum*

**Figure 3-6 FRFood Calibration: Green Bay Zone 2**
**Predicted vs. Observed Concentrations in Forage Fish**
**1989–1990**

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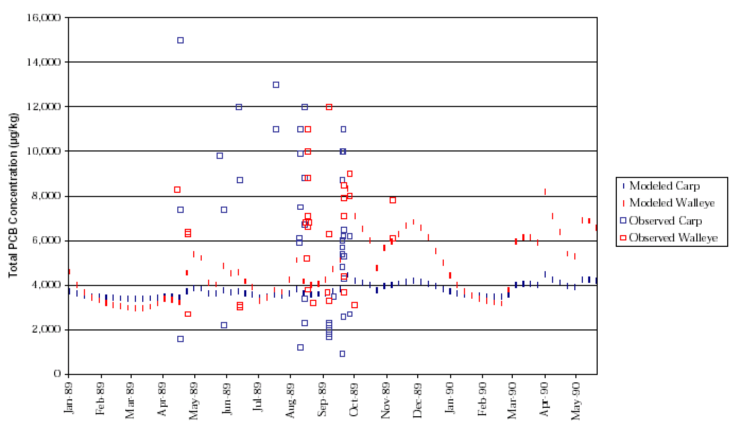
## Figure 8 FRFood Calibration: Green Bay Zone 2, Walleye and Carp

*Fox River Food (FRFood) Model Documentation Memorandum*

**Figure 3-7 FRFood Calibration: Green Bay Zone 2**
**Predicted vs. Observed Concentrations in Walleye and Carp**
**1989–1990**

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In addition, the commenter errs in citing The Mountain-Whisper-Light time trends analysis as "evidence" that trends in fish tissue concentrations are decreasing in the River. What specifically the Time Trends Analysis did report was that that the rate of decline in fish tissue concentrations observed through the 1970s changed from a decline, to either a steady state, or an increase in concentrations in fish tissue PCB concentrations. Several important fish species, including carp, perch, and walleye, show statistically significant slowing of the decline rate, with a breakpoint occurring in the trend in the early to mid-1980s. Carp in OU 4, for example, showed a significant increase in concentrations. This process and the errors in the commenters' analyses of the Time Trends Analysis are discussed in Master Comment 2.11 (98, 99, 207, 208, 209), and in *White Paper 1 No. – Time Trends Analysis*.

### Reference

Limno-Tech, 1998. *Review of RETEC Fox River Feasibility Study Draft Chapter 5, Section 5.1 "Contaminated Sediment Ranking."* Prepared for the Fox River Group by Limno-Tech, Inc. January 11.

## Master Comment 6.17

Commenters stated that since FRFood is a steady-state model, which limits its capability to reflect the delayed response of fish tissue PCB concentrations in response to changes in sediment and water column PCB concentrations. They further argue that a steady-state model such as FRFood cannot capture system responses that can be expected from active remediation.

## *Response*

The commenters are correct in that the original algorithms developed by Gobas reflect steady-state conditions; i.e., for a single point in time, the concentration reflected in the water column or sediment is reflected as an estimated concentration in the fish for that point in time. The model does not reflect how that concentration might change if no further exposure continued or if there were momentary spikes in chemical concentrations. If applied in and of itself, there are limitations to the applicability of this type of model for short-term predictions.

The purpose of applying the models was to account for long-term changes in PCB concentration in sediment, the water column, and ultimately fish tissue concentrations. When coupled with either wLFRM or GBTOXe, which provide output in much shorter timeframes (as frequently as one output per day), FRFood has the ability to project the expected concentration in fish. This ability to reflect shorter-term responses of PCB concentrations in fish can be seen on Figures 5, 6, 7, and 8, above, which represent the monthly fluctuation in PCB concentrations during the calibration period. As PCB concentrations spike during the spring and summer months, fish tissue concentrations also spike. As concentrations drop down to lower levels, fish concentrations of PCBs do as well. While it can be effectively argued that the model does not incorporate the lag that could be expected in response to a change in fish tissue concentrations, the Agencies do not view that as a liability of the model.

## Master Comment 6.18

Commenters stated that FRFood does not account for the effect of habitat and habitat preference on fish exposure to PCBs in sediments.

## *Response*

WDNR and EPA disagree with this statement. FRFood applied a scale appropriate for remedial decision-making on the Lower Fox River, as well as adequately considered "habitat preference" in model use.

A number of different aerial scales could have been applied throughout the RI/FS to evaluate and manage risk. The Agencies elected to evaluate risk on a reach-wide scale, although smaller units (e.g., deposits, SMUs) could have been independently evaluated. The Agencies believe that the appropriate scale for making remedial decisions and managing risk is at the OU level. Furthermore, the Agencies believe that restricted feeding areas, described as "microhabitats," are not appropriate for the Lower Fox River or Green Bay. Walleye, perch, carp, and other forage species examined in the RI/FS have wide home ranges, and it is not appropriate to restrict analyses to smaller units.

In addition, the Agencies believe that the commenters err in describing the routes of exposure for fish within the Lower Fox River and Green Bay. The food web and routes of potential exposure are described in both TM7b (Exponent) and TM7c (WDNR, 2001). Both the FRG consultants and WDNR fisheries biologists agree in both documents that the Lower Fox River food web is best described as a pelagic system, with a small component of the food chain being based upon benthic organisms. The major carbon-generating cycles occur within the water column, and not in the sediments. More specifically, PCB exposure and bioaccumulation occurs because of resuspension of sediments and uptake in the food chain via the water column. This may not be true for all species; carp, for example, are bottom feeders and these have been modeled accordingly. The persistence with which the commenters point to the sediment as an exposure route is not consistent with an analysis of habitat; the habitat "preference" for species within the Lower Fox River and Green Bay is in the water column, not sediment.

### References

Exponent, 1999. *Technical Memorandum 7a: Analysis of Bioaccumulation in the Fox River*. Prepared for the Fox River Group and the Wisconsin Department of Natural Resources by Exponent, Bellevue, Washington. February.

WDNR, 2001. *Technical Memorandum 7c: Recommended Approach for a Food Web/Bioaccumulation Assessment of the Lower Fox River/Green Bay Ecosystem*. Wisconsin Department of Natural Resources. January.

## Master Comment 6.19

Commenters stated that neither FRFood nor GBFood should be used to derive SQTs.

## *Response*

WDNR and EPA disagree with this comment. As noted in Master Comment 6.15, the underlying Gobas algorithms applied in FRFood have been successfully applied at several Superfund sites and in the development of the GLWQI criteria. The Agencies believe that the Gobas algorithms are demonstrably applicable in evaluating bioaccumulation. GBFood was not used in setting SQTs.

The Agencies also believe that FRFood is appropriately applied to setting SQTs. EPA Region 5 provided a guidance document on the use of bioaccumulation models for setting sediment cleanup goals in the Great Lakes (Pelka, 1998). However, and important distinction of SQTs is that they are not sediment cleanup goals. SQTs should be considered as receptor-specific point estimates; i.e., they are calculated for a specific sediment location, pathway, and receptor. The SQTs themselves are not cleanup criteria, but are a good approximation of protective sediment thresholds and were considered to be “working values” from which cleanup goals were selected. SQTs do not vary by OU, but may vary by Superfund site, given the type of contamination, the types of species, site-specific exposure potential, the location-specific information available at a specific Superfund site, etc. WDNR and EPA believe that the SQTs developed for the Lower Fox River and Green Bay site are specific site-wide.

See also Master Comment 4.8 (44, 67) and *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River*.

### Reference

Pelka, A., 1998. Bioaccumulation models and applications: Setting sediment cleanup goals in the Great Lakes. *Proceedings of the National Sediment Bioaccumulation Conference*. 5-9–5-30.

# 6.4 FoxSim (the Fox River Group Model)

## Master Comment 6.20

A group of commenters submitted an alternative model, known as FoxSim, and made various claims based on the forecasts generated by FoxSim and, in some cases, compared those forecasts to the modeling work identified in the *Model Documentation Report*.

## *Response*

In response to the submittal of this model and the various claims, WDNR's Water Quality Modeling Section reviewed FoxSim. The finding of that review was that the FoxSim model contains high uncertainties in its ability to predict PCB fate and transport in the Lower Fox River system. The model was constructed with a stated bias to "evaluate the on-going and future natural attenuation of the system." This is accomplished through the model's prediction of deposition of clean sediments and less scour of contaminated sediments, which leads to a prediction of less availability of PCBs to the water column and transport of PCBs within the River, and from the River to Green Bay. Please see *White Paper No. 15 – WDNR Evaluation of FoxSim Model Documentation* for more information.

## Master Comment 6.21

One Commenter stated that when using different models, the remedy from the Proposed Plan does little to reduce projected human health risks and that changes to numerical risk estimates are minor and are not significant, given the uncertainty of the analysis.

## *Response*

WDNR and EPA disagree with the foundation of this statement; that the models used in the RI/FS are flawed. Over the years, WDNR has worked cooperatively and collaboratively to develop the models that can be used as a tool to assist in decision making on this project. The Agencies' primary model is wLFRM. This model was initially developed as part of the Green Bay Mass Balance Study (GBMBS) as part of a suite of coupled water quality models describing PCB transport in the Lower Fox River and Green Bay were developed. Since the end of the GBMBS, efforts to examine and assess the performance of Lower Fox River water quality models have continued. Four generations of water quality model development have been initiated. The model developed as part of RI/FS efforts is the result of continued assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. To distinguish this model from prior generations of development, this fourth generation model is identified as the "whole" Lower Fox River model (wLFRM).

Development of the wLFRM was based on the results of a 1997 agreement and a peer review of model performance with the Fox River Group (FRG). A component of the agreement was to evaluate water quality models for the Lower Fox River and Green Bay with the intent of establishing goals to evaluate the quality of model results and a Model Evaluation Workgroup was formed (the Workgroup), and was comprised of technical representatives for the FRG and WDNR in order to undertake "cooperative and collaborative" evaluations of model performance. Development of a series of technical reports followed. The series of reports developed by the Workgroup were each prepared as a Technical Memorandum (TM) and are included in the Model Documentation Report. The TMs provide detailed analyses of key aspects of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions.

In addition to the Workgroup efforts, a peer review panel presented additional assessments of model performance. To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts. The wLFRM describes PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the River mouth at Green Bay in a single spatial domain.

More information on wLFRM development can be found in the Model Documentation Report which was prepared as a supporting document to the RI/FS and in *White Paper No. 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study and Proposed Remedial Action Plan.*

The models used to support these claims do not appear to have been subject to same degree of scientific scrutiny and peer review as was wLFRM. WDNR did review the FoxSim model. The conclusions of that review can be found in *White Paper No. 15 – WDNR Evaluation of FoxSim Model Documentation*.

# 7 Potential In-River Risks from Remedial Activities

## 7.1 Habitat Impacts from Dredging and Capping

### Master Comment 7.1

Several commenters expressed concerns that the Proposed Plan remedy would resuspend PCB concentrations in the water column, thereby increasing invertebrate and fish tissue PCB concentrations with a subsequent increase in ecological risks.

### *Response*

WDNR and EPA disagree with this assessment. Potential deleterious impacts on biota due to dredging and capping were analyzed in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*. Impacts analyzed included the effects from TSS, resuspension of toxic materials, physical removal of benthic populations, and change in substratum from cap placement.

The effects of TSS on aquatic biota have been studied for a wide variety of aquatic organisms. The general conclusion of those studies is that significant adverse impacts are not associated with typical dredging projects of uncontaminated materials, although some localized effects can occur at higher resuspended concentrations (Guannel et al., 2002). Those authors concluded that resuspended sediment concentrations caused by natural phenomena (floods, storms, winds, etc.) are often higher and of longer duration than those caused by dredging. This is well documented in the monitoring records of the pilot projects, Deposit N and SMU 56/57, as well as dredging projects where pre-dredging TSS measurements were more than double the levels observed during dredging (FRRAT, 2000).

Resuspension of contaminated sediments on aquatic biota has been more difficult to assess. PCBs at the levels reported in the two demonstration projects on the Lower Fox River are not likely to have an immediate, acute effect on the aquatic organisms. The BLRA for the Lower Fox River documents the levels of PCBs that are acute or chronically toxic to aquatic biota. The water quality monitoring conducted during the pilot dredging projects demonstrated that even during remediation at the most highly contaminated site in the River, PCB concentration did not approach these levels. Nor were those concentrations very different from PCB concentrations that have been observed in the water column absent dredging activity. Further, both dredging and capping have the potential to resuspend sediments, but the levels of resuspended solids and PCBs are lower than those naturally occurring in the Lower Fox River. Consequently, the effects from resuspension would be negligible

See also the response to Master Comments 7.16 and 5.4 and *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

### References

FRRAT, 2000. *Evaluation of the Effectiveness of Remediation Dredging: The Fox River Deposit N Demonstration Project November 1998–January 1999*. University of Wisconsin Water Resources Institute Special Report WRI SR 00-01.

Guannel, G., T. Wang, S. Cappellino, and C. Boudreau, 2002. Resuspended sediment effects in aquatic environments from dredging operations. *Proceedings of the Western Environmental Dredging Association Twenty-Second Technical Conference, June 12–15, 2002, Denver, Colorado*. p. 165–178.

## Master Comment 7.2

The commenters state that capping would have fewer negative impacts than dredging.

## *Response*

WDNR and EPA disagree with the comment that capping will have fewer negative impacts than dredging. Impacts from both capping and dredging are presented in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*. This white paper presents numerous case studies, which examined dredging effects on biota. While densities of benthic organisms were severely reduced in the short-term by dredging, recolonization was rapid (e.g., Wisconsin Spring Ponds and River Hull, England [Pearson, 1984]). *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River* also presented case studies examining effects on biota from capping. Currently, there are no good examples of capping projects that exist in any similar riverine system anywhere in the world. Consequently, this white paper examined other environs for comparisons. One case study, the Simpson capping project in Tacoma, Washington (Stivers and Sullivan, 1994), showed epibenthic populations and variability since cap construction has been similar to the ranges and variability found at various reference sites tested during the 5 years of monitoring. Another case study, Soda Lake, Wyoming (ThermoRetec, 2001c), found that 11 months following capping chironomids were approximately twice as abundant and oligochaetes were greater than six times as abundant at cap stations than off-cap stations. Shannon diversity was lower at both cap and off-cap stations than the baseline investigation, averaging 0.32 and 0.17, respectively. Prior to cap placement, oligochaetes were present at only five of the ten stations sampled, but dominated following cap placement. The substrate change from silt and clay to sand and the absence of organic content are likely the cause a decline in diversity.

### References

Pearson, R. G., 1984. Temporal changes in the composition and abundance of the macro-invertebrate communities of the River Hull. *Archiv fur Hydrobiologie*. 100:273–298.

Stivers, C. E. and R. Sullivan, 1994. Restoration and capping of contaminated sediments. In: *Dredging ’94: Proceedings of the Second International Conference on Dredging and Dredged Material Placement, 14–16 November 1994, Orlando, Florida*. E. C. McNair, Jr. (ed). American Society of Civil Engineers, New York, New York. p. 1017–1026.

## Master Comment 7.3

Numerous commenters had concerns that the remedial activities would cause damage to or loss of habitat for ecological receptors including negative food web impacts.

## *Response*

Potential deleterious impacts upon habitat were a consideration for the proposed remedies for the Lower Fox River. An analysis of the habitat impacts contained in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*, concluded that the remedial activities would have minimal impact on aquatic communities. Contrary to the comments concerning habitat, the analyses contained in that white paper found the following:

1) Dredging will not take place in sensitive wetland areas;

2) Current submerged aquatic vegetation (SAV) within the remedial areas is composed principally of Eurasian milfoil (*Myriophyllum spicatum*), an exotic invasive species, and a common floating pondweed (*Potamogeton* spp.);

3) Benthic invertebrate populations should recover quickly in depositional areas of the Lower Fox River following dredging activities; and

4) The Lower Fox River food web is pelagial not benthic, and therefore would be less impacted by removal activities.

Each of these items is discussed in more detail below with further relevant discussion in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

Marsh habitat is an important and sparse asset on the Lower Fox River, and any remedial alternative will weigh the environmental risks from PCBs left in place against the risks of loss of habitat. The remedy defined in the Proposed Plan does not impact the remaining marshes in the Lower Fox River. If during the final design, areas are found to exist that may impact marsh habitat, then the relative risk of leaving PCBs in place and allowing natural attenuation to occur will be weighed against the risk of loss of habitat. In Little Lake Butte des Morts, the marshland around Stroebe Island has been identified by the WDNR as a valuable spawning habitat for bluegill, sunfish, and bass, and the last remnant of northern pike spawning ground; it should not be a part of any ultimate removal or capping action.

There are very few areas where rooted SAV still exist within the Lower Fox River system. The SAV in the removal areas is composed primarily of Eurasian milfoil (*Myriophyllum spicatum*), a noxious invasive exotic species, and decomposing stands of common pondweed (*Potamogeton* spp.). Both species will quickly re-inhabit dredged areas. Capping will impact SAV to the same extent as dredging. An additional benefit of dredging will be the removal of nitrogen, phosphorus, and potassium, which contributes to eutrophication.

Recovery of benthic invertebrate populations from dredging and capping activities is discussed in response to Master Comment 7.1. Based upon case studies, the general expectation is immediate loss of benthic invertebrate populations followed by quick repopulation. Considerations for benthic repopulation were a component in the design of the remedial activities. For example, the extended dredging schedule will allow for organisms within the 1 ppm footprint yet to be dredged to serve as source populations for adjacent areas, which have already been dredged. The types and proximities of undisturbed areas near the dredged areas will likely provide substantial sources for recolonization. The areas not proposed for dredging have more coarse substrates that generally host more diverse benthic invertebrate populations. It is highly probable that these organisms will migrate to dredged areas as part of drift. As discussed below in the response to Master Comment 7.5, the Lower Fox River food web is pelagial not benthic, and therefore, impacts to benthos are expected to have negligible impacts to the remaining food web.

Fish will not be affected by any of the proposed remedial alternatives. Fish are generally able to avoid dredging activities and relocate to habitat suitable for their feeding and reproductive needs. The fish present in the Lower Fox

River are mobile species that seek out appropriate spawning habitat. Many naturally occurring backwater areas are present in Little Lake Butte des Morts as well as other artificial backwater areas resulting from dams in the Lower Fox River. These areas, along with tributaries entering along the entire River, are valuable backwater habitats that provide sources to which migration may occur and shelter during disturbances like dredging. Critical habitat for desired game species such as walleye or bass on the Lower Fox River are outside of the areas proposed for removal actions. Also, sufficient cover and spawning habitats provided by SAV are available before, during, and after dredging.

Either removal or isolation (dredging or capping) will have minimal overall impact to the food web. The food web of the Lower Fox River is referred to as a pelagic food web due to the heavy dependence on water column organisms and therefore will likely be unaffected by removal or isolation of benthic organisms. The fish in the Lower Fox River are primarily dependent on water column organisms, and although benthic organisms may be temporarily unavailable, the majority of the food organisms will be present in areas near dredging activities. See also the response to Master Comment 7.1 and *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

## Master Comment 7.4

Commenters opined that the FS and Proposed Plan failed to adequately assess the adverse environmental impacts of the proposed project, including the loss of SAV, substrate materials (gravel, snags), food sources essential for fish breeding and feeding, and food web impacts. Further, no attempts had been made to overlay areas to be dredged with an inventory of valuable habitat.

## *Response*

Many aspects of the concerns expressed by these commenters are addressed in the response to Master Comment 7.3. The concern over loss of substrate material was addressed in the Proposed Plan. Areas targeted for dredging or capping in the Lower Fox River are predominantly soft, aqueous, and silty sediments. As discussed in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*, fish in the Lower Fox River utilize open substrate like cobble with high dissolved oxygen for spawning and adult habitat. These areas are not targeted for dredging. Further, the NRDA restoration will target habitat enhancements, which is consistently called for by WDNR. Habitat enhancements contained in the remedy support the diversification of the fish assemblages within the River and the creation of more nearshore, shallow littoral habitat.

Finally, an overlay of areas to be dredged with an inventory of valuable habitat had been conducted in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

## Master Comment 7.5

Commenters complained that there has been no assessment of impact on the food web in general and specific fish populations in particular.

## *Response*

Effects on the food web from any active form of remediation has indeed been considered. For most of the Lower Fox River, a temporary disruption, displacement, and recolonization of benthic and fish populations will occur as incremental sections of the River are dredged and/or capped. Since the remedial programs will proceed incrementally, covering food sources, covering aquatic vegetation, and displacement of fish populations will occur. While commenters continue to try to place significance on the benthic component of the Lower Fox River food web, this is not a significant component. The Lower Fox River as a pelagic-based food chain has been documented and agreed to by both WDNR and the FRG (WDNR, 2001; Exponent, 1999). In short, neither dredging nor capping would produce any short-term real impacts to aquatic biota of the Lower Fox River. Dredging would not interrupt the pelagic component of the food web. Please see response to Master Comment 7.3 for a discussion of food web impacts. See also *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

### References

Exponent, 1999. *Technical Memorandum 7a: Analysis of Bioaccumulation in the Fox River*. Prepared for the Fox River Group and the Wisconsin Department of Natural Resources. Exponent, Bellevue, Washington. February.

WDNR, 2001. *Technical Memorandum 7c: Recommended Approach for a Food Web/Bioaccumulation Assessment of the Lower Fox River/Green Bay Ecosystem*. Wisconsin Department of Natural Resources, Madison, Wisconsin.

## Master Comment 7.6

The API Panel's conceptual model is also premised on its conclusion that the River as a fishery and wildlife habitat has been degraded by a variety of human activities and not just sediment contamination. Full recovery of the habitat values requires habitat restoration as well as management of the contaminants within the sediments. The conceptual model is based on the conclusion that fish/wildlife habitats degraded by human activities, not just contaminated sediments need habitat restoration/creation as well as sediments management.

## *Response*

WDNR and EPA concur with the goal of the statement above. It is consistent with the conceptual model on which CERCLA is based: remove the risk to health and the environment, and compensate for the environmental injuries caused by the release of the contaminants. The design and implementation of the selected remedial alternative must be conducted in a way that is sensitive to the ecological value of the action. The ROD will be prepared in consideration of these concepts, in addition to the reliability and permanence of the remedy.

## Master Comment 7.7

Commenters argued that Habitat Suitability Index (HIS) and In-stream Flow Incremental Methodology (IFIM) models should be used to determine habitat requirements for Lower Fox River fish. Habitat variables will be influenced by capping.

## *Response*

A wide variety of bottom substrates already exist in the Lower Fox River. Areas of cobble, gravel, sand, and soft substrate types are found throughout the River. A wide range of species is currently effectively using available habits. Spawning habitat may be limited to some extent for walleye and smallmouth bass in the Lower Fox River, but both are reproducing in the Lower Fox River, with walleye being fairly successful. However, the proposed capping material of sand and fine gravel has not been demonstrated to be the favored material for spawning. Walleye in the Lower Fox River and Green Bay prefer to spawn over large gravel and cobble with the greatest success occurring over 2- to 6-inch material. Smallmouth bass will spawn where finer materials are present but the finer substrates should be associated with larger gravel and cobble. Beyond the appropriateness of the size of the material, it is difficult to imagine that given unlimited resources and the mission to improve the habitat on the Lower Fox River, the choice would be made to cover extensive areas of the bottom substrate with a single, homogenous type of material. The Green Bay Remedial Action Plan (RAP) has long advocated for improved habitat, but the habitats that are deficient are extensive areas of rooted aquatics. Poor light penetration is the cause of the absence of this habitat, not improper substrate. Submergent macrophytes would help to provide habitat favoring the centrarchid family (primarily bluegill, largemouth bass, and pumpkinseed), which are poorly represented in the fish community.

## Master Comment 7.8

Commenters stated that filling the River with sand and gravel is not "habitat enhancement."

### *Response*

WDNR and EPA concur with this comment and this consideration was taken into account in the remedial design. Capping likely will have similar effects to dredging on aquatic vegetation and benthic invertebrate and fish communities; however, recovery of benthic invertebrate communities following capping likely will be slower than recovery following dredging due to decreased organic content of the sediment. Because of the lack of organic material in a potential sand or gravel cap, rooted SAV will likely not reestablish in areas where it was present prior to dredging until sufficient organic material accumulates on the cap. Seeds contained in the drift may settle in the sand or gravel cap; however, they are less likely to settle and root in the non-organic substrate. Further, the cap and gravel substrate will not be good walleye habitat if it is located in areas of low flow.

As discussed, in the response to Master Comment 7.4 above, habitat restoration is covered and will occur under the NRDA. See also, *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*.

## Master Comment 7.9

Commenters noted that the cap as proposed would require an enormous volume of sand and gravel that would need to be excavated locally in order to be cost-effective. This habitat destruction would offset any River habitat enhancement. The mined cap material would need to be transported and placed in the River with heavy equipment.

### *Response*

While WDNR and EPA agree there would be upland impacts from material mining, evaluation of upland habits from mining was outside the scope of the RI/FS.

## Master Comment 7.10

Commenters stated that, the Proposed Plan should include actions to minimize sedimentation that could lead to recontamination of the Site.

### *Response*

WDNR and EPA believe that implementation of a remedy at the 1 ppm action level will lead directly to a reduced loading of PCB-contaminated sediments.

While low levels of PCBs will remain in the system, the selected remedies do allow for the natural attenuation of the residuals over time.

# 7.2 Water Quality

## Master Comment 7.11

The commenters suggested that the proposed remedy claims to have selected an alternative "using environmental dredging techniques that minimize adverse environmental impacts, including resuspension of sediment during dredging," but offers no quantitative assessment of the potential negative consequences of PCB releases.

### *Response*

The Agencies believe that appropriate loading criteria from losses due to dredging should be equal to those determined during the dredging project at SMU 56/57. Based on these results, where the commenter acknowledged that this set of data represents the most comprehensive data set available, the PCB loss approximated 2.2 percent of the mass removed. Applying the loss rates from this project that removed the most highly contaminated sediment in the entire Lower Fox River to the proposed remediation would equate to a total loss of 644 kg of PCBs. If one were to accept the commenter's other opinion that the annual PCB export from July 2000 to July 2001 was up to 106 kg of PCBs and that the rate of decline approximates a half-life of 9 years at face value, over the next 20 years a significantly greater amount of PCBs will be resuspended from the River sediments and transported to Green Bay than active remediation. Similarly, the target removal of 1,700 kg of PCBs from Little Lake Butte des Morts would potentially release less than 40 kg of PCBs, an amount roughly only double the amount one commenter suggested is contributed by sediments annually to the loading leaving Little Lake Butte des Morts.

Relative to PCB concentrations, data collected during high-flow events or ship movements within the River have clearly shown that these actions frequently result in concentrations equal to concentrations found during dredging. Please also see the response to Master Comment 7.22.

## Master Comment 7.12

A commenter suggested the use of estimated releases of PCBs to the water column from other sites to infer losses that should be expected in the Lower Fox River.

## *Response*

WDNR and EPA believe that the resuspension losses of 2.2 percent documented at SMU 56/57 on the Lower Fox River are the most representative, relevant, and site-specific estimates available. WDNR and EPA agree that "Variations in site characteristics, the components of the remedy and their relevance to the lower Fox River, the method of sediment removal, the method and effectiveness of environmental controls, volume of sediment removed, and multiple contaminants of concern make direct comparisons between "successes" at other sites to the proposed project for the lower Fox River nearly impossible." Please also see the response to Master Comment 7.22.

## Master Comment 7.13

Commenters stated that dredging results in remobilization of PCBs to the water column.

## *Response*

Resuspension of PCBs and sediments due to dredging is a well-documented condition. However, it is concluded from the Lower Fox River demonstration projects that water column PCB levels, as a result of downstream transport of dredging-induced resuspension, will be a minor fraction of currently existing levels. Any increased loading will be minor relative to current conditions. Therefore, dredging-induced releases, which are short-term in nature, will not result in significant impacts to the River nor significantly affect the ensuing decline of PCB concentrations in sediments and water resulting from sediment removal. As documented during the dredging at SMU 56/57, normal River activities (e.g., vessel movement) have the potential to resuspend similar quantities of PCBs as does removal.

Water column parameters will be monitored during dredge operations in order to ensure that a minimal amount of PCBs will be transported downstream. PCB levels naturally fluctuate within the water column due to seasonal variables. In order to determine a threshold level for PCB concentration increases as a result of dredge operations for inclusion in the final remedial design, WDNR and EPA will likely resume dredging at SMU 56/57 in 2000, much as they did in the Consent Decree with Fort James. If the water samples during dredge operations indicate that the downstream PCBs transport is within the natural variation, then there will be no impact of dredging downstream. On the other hand, if surface water sampling finds levels of PCBs above the variation observed in "naturally" occurring concentrations, then further preventative measures will be employed in order to minimize the downstream impact.

## Master Comment 7.14

Commenters suggested that the proposed remedy would increase water column and fish tissue concentrations over the short term and will wreak considerable damage upon the ecosystem of Little Lake Butte des Morts.

### *Response*

The commenters did not provide any quantitative assessment that losses from dredging will be greater than losses from natural attenuation or capping. Therefore, a direct response cannot be provided as a result of the commenters' failure to provide details sufficient to back up their claim. However, one of the commenter's own analyses suggests that the total mass of PCBs lost under the natural attenuation option would exceed that from removal. Based on the results of dredging at SMU 56/57, where the commenter acknowledged that this set of data represents the most comprehensive data set available, the PCB loss approximated 2.2 percent of the mass removed.

Even applying the loss rates from the most highly contaminated site on the River to the entire Lower Fox River, proposed remediation would equate to a loss of 644 kg of PCBs. On the other hand, the commenter's offer that the annual PCB export from July 2000 to July 2001 was up to 106 kg and that the rate of decline approximates a half-life of 9 years. If one were to accept these numbers at face value, over the next 20 years almost 30 percent more PCBs would be resuspended from the River sediments and transported to Green Bay. Similarly, the commenter does not provide a basis for their claim that losses from a capping activity would be less than dredging. Lack of a quantitative comparison creates the illusion that the capping process would not cause loss of PCBs when in fact advective and diffusive losses in addition to direct resuspension of contaminated sediment will occur during placement of the cap and consolidation of the sediment below the cap.

## Master Comment 7.15

The Proposed Plan noted measurements of TSS during passage of a coal boat during the demonstration project at SMU 56/57 and related that to risk of sediment scour. Commenters noted that neither the FS or Proposed Plan provide a basis for the statement "the role and scale that commercial shipping traffic can play in resuspending and redistributing PCB-contaminated sediment within the navigation channel."

### *Response*

The monitoring funded by the FRG during the 1999 pilot dredging project at SMU 56/57 documented the increased turbidity and directly measured elevated PCB concentrations as a direct result of only the movement of the coal boat. The authors concluded that: "Vessel movement is a continuing PCB transport mechanism regardless of dredging operations." As the sediment is the only possible source of the elevated suspended solids and PCBs, this data documents that commercial ship traffic has the potential to locally scour sediments.

## Master Comment 7.16

A commenter observed that in Section 5.1, which attempts to discuss issues of risk reduction versus source removal, WDNR states without reference or support that "(m)any of the projects had elevated concentrations in the water column, surface sediments and caged fish tissues during dredging, although these releases were a fraction of the losses that would occur annually, assuming no removal would take place."

## *Response*

The 20 case study projects reviewed in Appendix B of the FS all measured surface water quality downstream of the dredging area. The measurement parameters ranged from turbidity, TSS, and/or chemical concentrations. The conclusions cited in all of these documents (when available) were that site-specific surface water quality action levels were not exceeded except in a few isolated and explainable cases (i.e., passing ships, silt curtain disturbance). The action levels developed for these projects were presumably protective of human health and the environment. Few studies, except for the Lower Fox River demonstration projects, have attempted to quantify the contaminant loss downstream during dredging as a mass and percent of mass removed. To date, WDNR and EPA are working with the best available data cited, explored, and documented in case study precedent.

It is concluded from the Lower Fox River demonstration projects that water column PCB levels as a result of downstream transport of dredging-induced resuspension will be a minor fraction of currently existing levels. The increased loads will also be small relative to current conditions. Therefore, dredging-induced releases, which are short-term in nature, will not result in significant impacts to the River nor significantly affect the ensuing decline of PCB concentrations in sediments and water resulting from sediment removal.

Water column parameters will be monitored during dredge operations in order to ensure that a minimal amount of PCBs will be transported downstream. Because PCB levels naturally fluctuate within the water column due to seasonal variables, WDNR will, during remedial design, determine a threshold level for a PCB concentration increase as a result of dredge operations. If the water samples during dredge operations indicate that the downstream PCBs transport is within the natural variation, then there will be no impact of dredging downstream. On the other hand, if surface water sampling finds levels of PCBs above the variation observed in "naturally" occurring concentrations, then further preventative measures will be employed in order to minimize the downstream impact.

This response concludes that the suspended solids increases due to dredging will be largely local (within a few hundred meters of the dredging operation) and not detectable above natural variation beyond this distance. Additionally, typical spring suspended solids levels are well above those predicted within the dredging plume.

## Master Comment 7.17

Commenters noted that intermediate project results (i.e., prior to completion of project dredging) are relevant, because they reflect PCB concentrations at a time when dredging activities have ceased (e.g., during winter and spring high-flow periods when dredging is not possible) and that residual PCB concentrations during implementation indicate a potential for significantly increased risk during proposed long-term dredging.

### *Response*

WDNR and EPA agree. Project scheduling is an important component of remedial design. WDNR and EPA will address this during remedial design following issuance of the ROD. WDNR and EPA wish to avoid the situation experienced following the first year of dredging at SMU 56/57 by the FRG where surface concentrations were significantly elevated. The remedial schedule will be done in such a way that annual dredging will be planned to be completed before weather conditions cause an increased risk of release and migration of temporarily exposed contaminants.

## Master Comment 7.18

A commenter observed that USGS concluded “if one is to monitor PCB transport during a remediation operation, sole reliance on turbidity or TSS measurements is inadequate. One must also directly measure the concentration of the contaminant of interest because exposed layers of contaminated sediment and exposed concentrated pore waters can contribute to particle and dissolved-phase PCB concentrations in downstream waters.”

### *Response*

Comment noted. The Agencies plan to include particulate and dissolved PCB fractions as well as TSS monitoring into the remedial design and construction activities even though only TSS measurements were required during the 2000 dredging at SMU 56/57 completed by Georgia Pacific.

## Master Comment 7.19

The commenter stated that dredging has the potential to increase exposure to mercury. The commenter pointed out that the RI reports significant concentrations of mercury in River sediment and suggests that dredging would release mercury into the water column and that dredging may also increase conversion to methylmercury.

### *Response*

Although each environmental sediment project is unique, case study precedent is often the best indicator of potential problems that may be expected during implementation of an active remedy. Other contaminated sediment dredging projects also retained mercury as a chemical of concern requiring remediation: Wyckoff/West Eagle Harbor in Washington and Minamata Bay in Japan. Maximum mercury concentrations detected site sediments were 32 and 7,600 ppm respectively. Cleanup levels were 5 and 25 ppm respectively with targeted dredge depths ranging from 3 to 7 feet deep. In the case of Wyckoff/West Eagle Harbor (mechanical dredging with silt curtains), the residual surface sediment concentrations met the target criteria, surface water quality during dredging operations was within acceptable criteria ranges, and the project is proceeding towards long-term risk reduction as anticipated. In the case of Minamata Bay (hydraulic dredging with suction and no silt curtains), mercury concentrations were reduced by 99 percent, surface water quality during dredging was within acceptable ranges, and long-term risk reduction of fish tissue concentrations and improvement of human health was achieved. Mercury concentrations in the Lower Fox River are mostly below 5 ppm with reach averages ranging from 1.2 to 2.4 ppm (mg/kg) mercury. There is also no evidence that the remedial activity will change the physical/biological processes necessary to increase the rate of mercury methylation in the River.

For the Lower Fox River project, mercury has been included as a component of the LTMP and will likely be measured in sediment and tissue during baseline and implementation sampling events to monitor adequate environmental protection.

## Master Comment 7.20

One commenter offered that PCBs from Lake Winnebago will continue to contribute to the River (despite dredging), inhibiting removal of fish advisories.

### *Response*

All of the historical data and records have clearly pointed out that Lower Fox River sediment PCBs are the major source contributing to Green Bay. The mass of PCBs existing in sediment of the Lower Fox River and the continual release of those PCBs are of greater concern than the negligible loading from Lake Winnebago.

## Master Comment 7.21

Commenters stated that much of the released PCB mass desorbs to the water column and exists in dissolved form, which silt curtains do not capture and that the FS has a flawed understanding of dredging-induced PCB releases.

### *Response*

While problems with turbidity barriers were noted at sites such as the Grasse River, GM Central Foundry, and the Outboard Marine Site, it is important to note that the difficulties encountered at these sites were due to: (1) variable winds and current speeds in excess of those at which the barriers are effective, and/or (2) improper barrier design for site conditions.

Review of available Lower Fox River water quality data from the two demonstration projects, conducted at SMU 56/57 and Deposit N, indicate little difference between upstream and downstream TSS concentrations (USGS, 2000) when averaged over the length of the project. These projects also measured dissolved and total PCB concentrations in the water column during dredging, instead of relying solely on TSS measurements. The Lower Fox River demonstration project conducted a PCB mass balance of the entire treatment train during dredging and calculated an approximate 2 percent PCB loss downstream during dredging. It is unreasonable to expect that any active remedy (capping or dredging) conducted in the River will result in zero percent release and transport of contaminated sediments and PCBs. Some release will occur, but the projects need to define acceptable levels of TSS and PCBs. In fact, the case study review of dredging projects (Appendix B of the FS) found that individual projects developed water quality action levels during dredging (often based on mixing zone models) and that very few of these action levels were exceeded during dredging.

The use of silt curtains or other barrier devices will be determined during the project's design phase with input from the selected dredging contractor. Minimal costs for using silt curtains were included in the FS costs, but design, implementation, and deployment will ultimately be determined by the design team. Based on the monitoring results from the Deposit N demonstration project, it is possible that silt curtains will not be used at all. Please also see the response to Master Comment 7.22.

### Reference

USGS, 2000. *A Mass-Balance Approach for Assessing PCB Movement during Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. United States Geological Survey Water-Resources Investigations Report 00-4245. United States Geological Survey. December.

## Master Comment 7.22

A commenter noted that achieving the goals of RAO 5 may require incorporation of measures to control contaminant releases during remediation. TSS monitoring or turbidity is inadequate since PCBs exist in dissolved form, which silt curtains don't capture.

## *Response*

As noted in Master Comment 7.21, measured total suspended solids concentrations from the two demonstration projects, conducted at SMU 56/57 and Deposit N, showed very little difference between upstream and downstream TSS concentrations (USGS, 2000) when averaged over the length of the project.  This information is consistent with an analysis done for the Hudson River Site (White Paper 336740), Resuspension of PCBs During Dredging, January 2002, which showed that for five projects representing 388 observations, the average resuspension loss on a volume to volume basis average 0.11 percent.

The two demonstration projects on the Fox River also measured dissolved and total PCB concentration in the water column during dredging, instead of relying solely on TSS measurements.  On a mass basis (mass lost to mass removed), the loss was found to be 2.2 percent PCB loss downstream during dredging.  These losses are relatively small, particularly when compared to ongoing releases from natural processes, which would continue on an indefinite and ongoing basis, assuming no action.  Applying this relative loss to the total mass of PCBs consistent with the Proposed Plan (OUs 1, 3, and 4) would result in a total loss of approximately 46 pounds over an estimated 7-year dredging project (assuming removal of 64,500 pounds).  This would provide an annual average release of less than 7 pounds per year.  This compares to PCB loading from the Lower Fox River into Green Bay between 183 and 486 pounds per year.  Without remediation, this ongoing release would continue indefinitely, whereas the 7 pounds per year would stop after completion of dredging.

The Lower Fox River remedial design would utilize similar equipment and protective measures to those evaluated in the study referenced above and would produce similar results.

### Reference

USGS, 2000. *A Mass-Balance Approach for Assessing PCB Movement during Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. United States Geological Survey Water-Resources Investigations Report 00-4245. United States Geological Survey. December.

## Master Comment 7.23

Commenters noted that dredging will cause releases into the water column of PCBs that are currently in the sediment bed and that such release rates at the 2 demonstration projects were approximately 2.2 percent. The commenters also noted that silt curtains cannot control the movement of dissolved PCBs and the draft RI/FS assumed that no such release would occur.

## *Response*

While problems with turbidity barriers were noted at sites such as the Grasse River, GM Central Foundry, and the Outboard Marine Site, it is important to note that the difficulties encountered at these sites were due to: (1) variable winds and current speeds in excess of those at which the barriers are effective, and/or (2) improper barrier design for site conditions.

Review of available Lower Fox River water quality data from the two demonstration projects, conducted at SMU 56/57 and Deposit N, indicate little difference between upstream and downstream TSS concentrations (USGS, 2000) when averaged over the length of the project. These projects also measured dissolved and total PCB concentrations in the water column during dredging, instead of relying solely on TSS measurements. The Lower Fox River demonstration project conducted a PCB mass balance of the entire treatment train during dredging and calculated an approximate 2 percent PCB loss downstream during dredging. It is unreasonable to expect that any active remedy (capping or dredging) conducted in the River will result in zero percent release and transport of contaminated sediments and PCBs. Some release will occur, but the projects need to define acceptable levels of TSS and PCBs. In fact, the case study review of dredging projects (Appendix B of the FS) found that individual projects developed water quality action levels during dredging (often based on mixing zone models) and that very few of these action levels were exceeded during dredging.

The use, or no use, of silt curtains or other barrier devices will be determined during the project's design phase with input from the selected dredging contractor. Minimal costs for using silt curtains were included in the FS costs, but design, implementation, and deployment will be ultimately be determined by the design team. Based on the monitoring results from the Deposit N demonstration project, it is possible that silt curtains will not be used at all.

## Reference

USGS, 2000. *A Mass-Balance Approach for Assessing PCB Movement during Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. USGS Water-Resources Investigations Report 00-4245. United States Geological Survey. December.

# 8 Implementability of Remedial Alternatives

## 8.1 Implementability of Dredging

### Master Comment 8.1

Commenters noted the challenges that the demonstration dredging projects experienced: riverbed debris, sediment resuspension, and residual contamination of surface sediments. A commenter suggested that these problems can be avoided with: proper dredge equipment, successful construction, operation, decommission, adequate water treatment, and proper materials management/disposal.

### *Response*

This is a principal finding of the *Sediment Technologies Memorandum* (discussed in Section 5.1.1 of this RS). This is not to trivialize the important engineering challenges that will be faced during the remedial design and implementation phase, but WDNR and EPA believe that these can be managed for the Lower Fox River.

### Master Comment 8.2

Commenters maintained that the removal action proposed for the Lower Fox River would result in the destruction of habitat and impact important ecological resources on the River. The commenters suggest that a remedy impact analysis showed that dredging would result in the loss of SAV beds, which offers important habitat to invertebrates and fish. The commenters also suggest that the benthic infauna of the River will be lost with dredging, resulting in deleterious effects in the food chain.

### *Response*

WDNR and EPA believe that the remedy impact analysis overstates the environmental issues listed in that document. As discussed in responses to comments in Section 7.2 of this RS, and in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River*, important wetlands and marshlands identified in the River are outside the remedial action footprint. Furthermore, the SAV identified within the remedial footprint is principally the exotic Eurasian milfoil and floating stands of pondweed. Benthic infaunal habitat will be lost during removal, but the species of midges and segmented worms found in the Lower Fox River will quickly recolonize post-dredging. Finally, the impacts to benthos are of less concern, as the Lower Fox River food chain is principally pelagic-based.

## Master Comment 8.3

A commenter disagreed with the FS's analysis of the effectiveness, implementability, and cost of large-scale dredging and disposal. The commenter stated that the FS does not adequately account for the drawbacks of dredging or the track record of dredging at other sites. The effectiveness of dredging must be evaluated in the context of risk reduction.

## *Response*

As presented in Appendix B of the FS, the *Sediment Technologies Memorandum* provided a comprehensive evaluation of dredging projects and concluded that dredging has been successfully implemented at various sites. The "lessons learned" from these dredging projects have been considered while preparing the FS. Based on the experiences at previous dredging projects, hydraulic (cutterhead suction dredge), and mechanical dredge (clamshell bucket) have been considered in the FS. The final selection of the dredging equipment will occur during the design phase of the project. Several factors will influence the final selection that include detailed engineering planning and analysis conducted during the design phase and information obtained from potential contractors. Due to technical advancement, numerous improvements have been made to the dredging technologies. Beyond the hydraulic and mechanical dredging technologies identified in the FS, it may be necessary to review specialty equipment dredges during the design phase for potential removal operations at the Lower Fox River.

## Master Comment 8.4

The implementability of dredging was brought into question by commenters who argued that the remediation of the Lower Fox River represents the largest and most complex remediation in the United States regardless of the alternative selected (capping or dredging). They further argue that on this basis, neither remedial technology has advantages in terms of previous successes in the United States.

## *Response*

WDNR and EPA disagree with this comment. Dredging and capping experience are not comparable in terms of size and number of projects implemented. Nor is the remedial action proposed for the Lower Fox River the largest dredging program ever undertaken.

There have been over 100 years of experience with dredging projects around the world. Navigational dredging projects commonly dredge large volumes of sediment in a short timeframe. Typically, about 4 million cy of sediments are dredged by the USACE each year from Great Lakes harbors and channels. This is only a portion of the 300 to 350 million cy dredged by the USACE nationwide annually. On average, the USACE spends about $20 million annually for dredging and dredged material management in the Great Lakes basin (USACE website: http://www.lrd.usace.army.mil/gl/dredge.htm). The Port of Los Angeles hydraulically dredged and landfilled about 29 million cy of sediment for the Pier 400 construction project (1994 through 2000). Minamata Bay, Japan and Lake Ketelmeer, Netherlands, two of the largest international contaminated sediment dredging projects (that WDNR and EPA know of) dredged 1 million cy of mercury-impacted sediment in 4 years, and 1.9 million cy of impacted sediment in 1 year, respectively. Other large contaminated sediments management projects include the Slufter Depot for the Port of Rotterdam, and restoration of Lake Tunis in Tunisia. The Ketelmeer project covers a larger area and volume than the proposed action for the Lower Fox River, and is already well into the construction phase (Roukema et al., 1998).

Other sediment remedial projects that will be similar in scale in the United States include the removal action on the Hudson River in New York, the Hylebos and Thea Foss waterways in Washington, and the Kalamazoo River in Michigan.

By contrast, national and international engineered capping projects have been much smaller in scale and have only been implemented in the last 25 years. Table 3 of *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* contains a list of the comparatively few dredging projects that have been built, and monitored, only since 1984. Most of these projects are less than 50 acres.

### Reference

Roukema, D. C., J. Driebergen, and A. G. Fase, 1998. Realisation of the Ketelmeer Storage Depot. *Terra et Aqua 71*. Website: http://www.iadc-dredging.com/terra%2Det%2Daqua/1998/71%2D3.htm.

## Master Comment 8.5

Commenters expressed concern that dredging and the resultant resuspension of sediments have the potential to interfere with industrial processes requiring clean intake water. In addition, the proposed dredging schedule may interfere with commercial shipping and may affect shoreline stability, posing a risk to recreation, commerce, and the environment. Monitored natural attenuation reduces all these risks and is likely to be acceptable to the community.

## *Response*

WDNR is unaware of any industrial water intake quality issues in the River associated with either navigational or environmental dredging projects on the Lower Fox River. The USACE performs regular navigational dredging on the lower portion of the River and the WDNR has not been notified of any problems from water users. Resuspension issues are discussed in Section 5.1.2 of this Responsiveness Summary.

On the two environmental dredging pilot projects performed on the River over the period 1998 through 2000, detailed monitoring of the River and of the water withdrawn by nearby industries had shown no degradation to the quality of water withdrawn for industrial uses. These industrial users were located very close to the dredging projects.

Commercial shipping on the River is confined to the lower few miles of the Lower Fox River. Dredging activities in the past for both navigation and for the environmental dredging pilot have been performed without interference to commercial navigation. WDNR and EPA have every reason to believe that future dredging projects can be implemented in a manner that fully accommodates commercial navigation. This is supported by the fact that dredging activities only impact a relatively small portion of the River at a single point in time.

## Master Comment 8.6

Commenters suggested that remedial success based on mass removal effectiveness is misleading and that for the Lower Fox River the mass is diffuse and there are no “hotspot” areas.

## *Response*

WDNR and EPA do not agree with the premise that, in the Lower Fox River, PCB mass is diffuse and widespread with no hot spots. The RI/FS clearly shows that the Lower Fox River does indeed contain hot spots; for example, Deposit A, Deposit POG, Deposit N, and SMU 56/57. Concentrations in these deposits range up to the hundreds of parts per million. Furthermore, this comment is misleading in that it suggests that the remedy is mass-driven when, in fact, the remedy is based on risk reduction.

## Master Comment 8.7

A commenter stated that the FS did not use a “realistic solids content” for estimates in the FS. Based on the results from SMU 56/57, they argue that those levels should be 4 percent for the first pass and 2 to 4 percent for the second pass.

## *Response*

WDNR and EPA agree that realistic dredge solids concentrations should be used in estimating production rates. The SMU 56/57 2000 project dredge solids concentrations ranged from 3.5 to 14.4 percent with an average of 8.4 percent. Since these concentrations reflect multiple passes, use of the 8.4 percent average for this project is a reasonable assumption. This value is similar to 5 of the 8 values submitted with Table 8 of the comment (FRG Comments, Volume 1, p. 252). The dredge sediment percent solids will be considered in greater detail during the design phase of the project.

## Master Comment 8.8

Several comments were received concerning the use of silt curtains to control resuspension losses during dredging. These included comments that support the use of anchored silt curtains at all sites as is outlined in the FS. Other comments stated that silt curtains would be difficult to implement, not provide any additional protection, and have a poor application record at the demonstration projects.

## *Response*

While the use of silt curtains were applied universally for the entire River in construction of the alternatives and costs, the FS did indicate that silt curtains may not be appropriate at all sites. As commenters correctly point out, currents, ability to anchor, obstructions, and interference with navigation uses, need to be considered with the final design. Silt curtains were applied throughout the FS as a general process option. Final determination on the need for or use of silt curtains in the Lower Fox River is a design issue and will be determined by the design engineer and dredge contractor.

## Master Comment 8.9

Comments were received concerning the presence and importance of considering physical obstacles (water intakes, outfalls, piles, cables, pipelines, etc.) in planning for a remedial action. They submit that the FS and Proposed Plan did not evaluate the impact on the proposed remedy of any of these with regards to cost, effectiveness, and implementability.

## *Response*

WDNR acknowledges that there will be physical obstructions in the downstream portion of the Lower Fox River that will need to be dealt with in any implemented remedial alternatives. The *Sediment Technologies Memorandum* documented that one of the important components that had to be built into remedy design is allowance for debris management. In the Draft FS, obstruction removal was not specifically accounted for. In the Final FS, the costs associated with debris sweeps have been specifically accounted for.

## Master Comment 8.10

One commenter noted that it may not always be possible to use over-dredging or “overbite” to improve removal efficiency.

### *Response*

WDNR agrees that it is not always feasible to use over-dredging to improve removal efficiency. However, as identified in the FS, over-dredging of sediments will be accomplished only when possible and necessary. There are several areas within the dredge footprint of the River, where sediments will be dredged to hard bottom, which eliminates the need for over-dredging. The residual contamination depends on a number of factors that include depth and type of materials underlying the dredge footprint, average PCB concentration of sediments, depth of cut, and cleanup goal for project. These conditions are site-specific and vary by projects. Results from the *Sediment Technologies Memorandum* (Appendix B of the Draft FS) indicate that dredging can be implemented in an effective way if the technology is designed and managed appropriately for the Site conditions. Recent advances in the dredge head construction and positioning technology enable accurate removal of sediment layers with minimum incidental over-dredging to achieve target goals. As stated in the FS, 17 of the 20 projects mentioned in Appendix B met the short-term target goals that includes sediment excavation to a chemical concentration, mass, horizon, elevation, or depth compliance criteria. Seven projects designed “over-dredge” into the project plans. In five out of seven cases, where over-dredge could occur, target goals were met.

## Master Comment 8.11

Commenters believe EPA’s final ROD should specify hydraulic suction dredging as the default sediment removal technology because:

1) Hydraulic dredging produces the lowest levels of sediment resuspension;

2) Hydraulic dredging can be engineered to minimize volatilization;

3) Hydraulic dredging works faster than mechanical dredging; and

4) The ability to pipe sediment slurry as far as 10 miles can reduce equipment traffic on the River and eliminate heavy truck traffic on regional roadways.

### *Response*

WDNR agrees with the commenter that hydraulic dredging can be effectively used to control sediment resuspension, engineered to minimize volatilization, and connect to a sediment slurry line to minimize equipment traffic. Due to technical advancement, numerous improvements have been made to mechanical dredges (clamshell buckets) to limit the release of excavated sediments, thereby minimizing sediment resuspension. Due to unique characteristics presented by the River (bathymetry) and community (upland space for staging areas and processing areas), the Agencies are allowing flexibility in the implementation of dredging in order to allow the contractor the most efficient and cost-effective technology. Both hydraulic and mechanical dredging technologies have been demonstrated to provide a protective and environmentally beneficial result (FS Appendix B). Therefore, either technology is appropriate for removal of PCB-contaminated sediments from the Lower Fox River.

## Master Comment 8.12

Commenters believe that a careful hydraulic dredging technique coupled with the use of silt curtains can minimize resuspension of contaminated sediment. The commenters stated that the long-term risks associated with the current annual loading of PCBs to Green Bay, if allowed to continue for an extended period, far outweigh the short-term risks associated with resuspension losses due to dredging.

## *Response*

WDNR and EPA concur with the comment and believe that the commenters' opinion is consistent with the FS.

## Master Comment 8.13

Commenters stated that the two dredging demonstrations recently done on the Lower Fox River showed that dredging can be effective at removing large volumes of sediment fairly quickly, with minimal drift downstream. However, the demonstrations also exposed several management problems that must be addressed before additional dredging is done:

1) Experienced operators must be hired.

2) Contractors must have clear guidelines and contracts to follow as established by the Agencies, and timelines and performance standards to meet with requirements for frequent reporting of progress and problems.

3) The government must retain oversight if the contractors are hired by the paper corporations.

4) Make sure the dredging starts on each sediment bed early enough to complete in one season, before the winter freeze-up of the River or Bay.

5) If a hotspot is too big to complete in one season, make sure the contractors slope the sides of the hole and cap the exposed edges for the winter to reduce the risk of toxic leakage between dredging seasons.

6) Make sure the contractors have multiple backup dredges and excess treatment capacity on land to compensate for unavoidable frequent equipment breakdown.

7) Have contractors dredge to below the sediment layers known to be contaminated to ensure they get all the toxics.

8) Even if the dredging results in some leakage downstream, the sediments are currently leaking 300 to 500 pounds of PCBs per year down the Lower Fox River.

## *Response*

WDNR and EPA agree with the sentiments expressed in these comments. The Agencies will use pertinent comments as the design stage of this project is entered.

## Master Comment 8.14

A commenter stated that the skills and technology are not available to remove nearly 9 million cy of sediment in the 7 years that the Proposed Plan estimates the entire dredging project will take to perform.

## *Response*

First of all, the estimated volume of contaminated sediment to be removed from the River is estimated to by 7.25 million cy, not 9 million cy. It is expected that many of the dredging and mobilization activities will occur in parallel between operable units. WDNR will begin sediment sampling and analysis subsequent to issuance of a ROD, and will also initiate contractor selection. Contractor selection involves preparation of requests for qualifications followed by review of contractor submittals and then release of bid packages to qualified contracting teams. It is currently anticipated that there will be approximately 30 months available to accomplish remedial design; this is considered adequate time to complete the associated tasks.

Navigational dredging projects commonly dredge large volumes of sediment in a short timeframe. Typically, about 4 million cy of sediments are dredged by the USACE each year from Great Lakes harbors and channels. This is equivalent to 400,000 truckloads of soil. This is only a portion of the 300 to 350 million cy dredged by the USACE nationwide annually. On average, the USACE spends about $20 million annually for dredging and dredged material management in the Great Lakes basin (USACE's website: http://www.lrd.usace.army.mil/gl/dredge.htm, 2002). A project-specific example includes the White Rock Lake sediment dredging project, described in the Lower Fox River and Green Bay FS (Section 6) as the 20-mile-long pipeline project in Texas, hydraulically dredged 3 million cy of sediment in 1 year. Slurry solids content was 10 to 15 percent, comprised mostly of silt, clay, and debris. WDNR and EPA acknowledge that site conditions in the Lower Fox River are expectedly different from White Rock Lake, but for comparison purposes, this rate would equate to 7 million cy of sediment in 2.5 years. The Port of Los Angeles hydraulically dredged and landfilled about 29 million cy of sediment for the Pier 400 construction project (1994 through 2000). Minamata Bay, Japan and Lake Ketelmeer, Netherlands, two of the largest international contaminated sediment dredging projects (that WDNR and EPA know of) dredged 1 million cy of mercury-impacted sediment in 4 years and 1.9 million cy of impacted sediment in 1 year, respectively.

Factors that could create delays and downtime such as River congestion, weather, and equipment problems have been considered. Since productivity estimates applied in the FS were based on dredging equipment operating between 48 percent (mechanical) and 61 percent (hydraulic) of the week, considerable margin has been left to manage potential delaying factors such as those mentioned herein. WDNR believes that congestion problems can be avoided if project equipment movements are scheduled, as much as possible, for off-peak periods. Weather-related downtime includes delays from high flows, low temperatures, and high winds. After reviewing meteorological data, the potential for weather-related delays has been accounted for in the calculation of downtime. Finally, delays from equipment malfunctions and equipment unavailability need not represent major difficulties because extensive planning will occur at the outset of work and attention will be given to management of the overall remedial program.

## 8.2 Dredging Schedule and Production Rates

### Master Comment 8.15

Commenters argued that the Proposed Plan's dredging rate estimates are too optimistic and are not typical of environmental dredging rates. The commenters argue that more appropriate rates would include 200 cubic yards per hour (cy/hr) for "first pass" dredging, and 100 cy/hr for "cleanup pass" dredging, which would also include 8 inches of over-dredged sediment. Based on their estimates, OU 1 would require 5.2 years for removal, OU 3 2.9 years, and OU 4 22.1 years. A key assumption was that only one hydraulic dredge can operate at each reach in order to minimize turbidity, TSS and PCB resuspension, and boat and ship traffic interference.

### *Response*

There are two types of hydraulic dredges considered in the cost estimates for the Lower Fox River in the FS. The average dredge production rate for a 10-inch cutterhead dredge in a 10-hour shift is 105 cy/hr and the average dredge production rate for a 12-inch cutterhead dredge in a 12-hour shift is

120 cy/hr. These dredge rates are within the estimates used by the FRG model (100 to 200 cy/hr) to account for “first pass” and “cleanup pass” dredging.

The case studies presented in Appendix B of the FS indicate that the dredge rates in the Proposed Plan are not unreasonable for environmental dredging. For example, dredge production rates at the SMU 56/57 demonstration project averaged 60 cy/hr and 294 cy/day.

The commenter does not present the dredge production rates on the same basis. The commenter used different dredge equipment, sizing, and operating assumptions to derive the elongated schedule. For example, in OU 1 the FRG assumed 200 cy/hr for first pass dredging and 100 cy/hr for second pass dredging, operating 10 hours per day, 5 days per week, and 26 weeks per year. The resulting dredge duration is 681 days or 5.2 years. The FS assumed operating 10 hours per day, 5 days per week, and 26 weeks per year utilizing a 105 cy/hr dredge. This results in a total dredge timeframe of 5.7 years, slightly more than the FRG’s timeframe due to a lower dredge rate.

For OU 3, the FRG assumes one hydraulic dredge operating 12 hours per day, 6 days per week, and 26 weeks per year. This results in a dredge timeframe of 454 days or 2.9 years. The commenters’ argument that only one dredge can operate at any single time in either OU 3 or OU 4 is not a supportable position; there are no restrictions that prevent multiple dredges from operating in any OU. The FS describes two 12-inch cutterhead dredges operating simultaneously 12 hours per day, 7 days per week, 26 weeks per year, and a dredge rate of 240 cy/hr per dredge (840 cy/hr for two dredges). The resulting dredge duration is 102 days or 0.7 year, lower than the FRG’s timeframe due to a higher dredge rate.

Finally for OU 4, the FRG assumes one hydraulic dredge operating 12 hours per day, 6 days per week, and 26 weeks per year. This results in a dredge timeframe of 3,448 days or 22.1 years. The FS describes two 12-inch cutterhead dredges operating simultaneously 12 hours per day, 7 days per week, 26 weeks per year, and a dredge rate of 240 cy/hr per dredge (840 cy/hr for two dredges). The resulting dredge duration is 1,019 days or 6.8 years, lower than the FRG’s timeframe due to a higher dredge rate.

## Master Comment 8.16

A commenter stated that the options for wastewater disposal are: (1) pre-treat water and discharge to a POTW (indirect discharge), or (2) complete treatment on Site and discharge directly to the River. The commenter expressed the opinion that both options are problematic; Appleton and Green Bay are the only two potential POTWs, and hydraulic and bioaccumulative/toxic impacts to POTWs make it a non-viable option.

Further, discharges to Appleton or Green Bay treatment works (largest in the area) would add approximately 100 and 500 percent, respectively, more wastewater – stretching or exceeding current operating capacities. Finally, the commenters stated that this wastewater could not be directly discharged to the River because of unwieldy facility size (the amount of water would be too great).

### *Response*

The Proposed Plan does not recommend the discharge of sediment remediation wastewater to the Appleton, Green Bay MSD, or any other publicly owned wastewater treatment facility (WWTF). The Proposed Plan proposes to construct separate dedicated WWTFs with direct discharge to the Lower Fox River. Discussions with consultants and contractors with substantial experience designing, building, and operating these types of remediation projects have not identified the sizing, siting, and construction of WWTFs as a limiting factor. These issues must be considered for all projects and will be addressed in more detail during the design phase. The WDNR does not believe these issues threaten the viability of the Proposed Plan, and did not find any specific obstacles presented in the API Panel's or any other comments. Related issues are discussed in *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits*.

Please also see response to Master Comment 5.52 through 5.60.

### Master Comment 8.17

The commenters stated that the dredging recommended in the Proposed Plan was not viable because the quality and quantity of wastewater generated in the dredging process could not comply with water quality standards and associated WPDES permit limits, even using the most advanced wastewater treatment process. The wastewater quantity and quality limitations would, therefore, restrict the allowable wastewater discharge rate, thereby decreasing the allowable dredging rate and increasing the dredge schedule from the 7 years estimated in the Proposed Plan to as much as 60 years. Based on these assumptions, the commenters concluded that in-place sediment capping was the only viable alternative for remediation of the Lower Fox River sediment.

### *Response*

In response to these comments, the WDNR analyzed the assumptions used to support the comment conclusions and performed an evaluation to determine if the expected dredge process wastewater characteristics and volumes would restrict or limit the viability of the Proposed Plan as claimed in the comments. The complete analysis is presented in *White Paper No. 7 – Lower Fox River*

*Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits*.

This analysis concluded that the dredge process wastewater quantity and/or quality do not restrict the viability of dredging as recommended in the Proposed Plan, and do not, by themselves, justify the API Panel's alternative capping proposal. This evaluation essentially concludes that the expected quality and quantity of the dredge process effluent will comply with Water Quality Based Effluent Limits (WQBEL), and will not restrict the effluent discharge rate or associated dredge schedule. The expected effluent quality and quantity do not therefore limit the viability of the proposed remedial dredging project.

Additional significant specific conclusions from *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits* include:

- The wastewater quality achieved from the Lower Fox River Deposit N and SMU 56/57 demonstration projects provides the best representation of the effluent quality expected from the full-scale dredging of the Lower Fox River. These data should be used for estimating expected effluent quality, not those assumed by the commenters.

- Effluent quality would not limit the ability of the project to comply with expected wastewater WPDES permit limits.

- Effluent quality would not restrict the expected effluent discharge rate based on the Lower Fox River assimilative capacity for cadmium, dieldrin, endrin, mercury, or any other parameter.

- The WQBEL for toxic and organoleptic compounds regulated under WAC NR 106 are only needed for PCBs and mercury.

- PCBs and mercury WQBELs will be determined using the alternative limit procedures provided in NR 106.06(6), because background Lower Fox River concentrations of PCBs and mercury exceed water quality standards.

- The Lower Fox River assimilative capacity for BOD is indeed fully allocated, however, much of that capacity is unused by the permitted discharger. Effluent from full-scale implementation of the proposed dredging plan would only use a small portion (less than 10 percent) of the unused or available assimilative capacity of the River.

- A significant portion of unused capacity is held by the PRPs and can be formally or informally reallocated to the discharge of the remediation project.
- Effluent quantity estimates contained in the comments are not reasonable, do not limit the allowable dredge rate, and would not extend the dredge schedule beyond that estimated in the Proposed Plan.
- Discharges from two pilot dredging projects have been permitted under Wisconsin regulations.

## Master Comment 8.18

Commenters expressed concerns that the proposed remedy could not be completed according to the timeframe described in the FS and Proposed Plan. Dredging rate assumptions are higher than dredging rates achieved on the best days of both the 1999 and 2000 demonstrations projects at SMU 56/57.

## *Response*

The dredging rates proposed for the Lower Fox River were determined based on site-specific dredging rates produced from the Lower Fox River demonstration projects at Deposit N and SMU 56/57. These rates were reviewed by nationally recognized dredging engineers and contractors and applied to the FS. WDNR recognizes that the Proposed Plan for large-scale dredging of the Lower Fox River constitutes one of the largest environmental dredging projects in the United States, but the volumetric scale of dredging is not unusual for navigational projects typically and annually conducted in the United States by the USACE. Careful coordination of dredging, dewatering, and disposal parameters will be refined during the pre-remedial design phase to meet the timeframe desired by WDNR.

The dredge production rates were determined based on experience with previous dredging projects and consultation with experienced dredge contractors. Downtime of approximately 17 percent has been factored into the dredge production rates. The dredge production rate specified for hydraulic dredge with cutterhead in the Draft 2001 RI/FS is 1,050 to 1,200 cy/day. The case studies presented in Appendix B of the FS indicate that the proposed dredge rates are not unreasonable for environmental dredging. The dredge production rate from both Lower Fox River demonstration projects was considered and evaluated throughout the drafting and finalizing of the FS. Other considerations included an examination of physical sediment conditions throughout the entire River (e.g., grain size, *in-situ* bulk density). Finally, considerable experience at other sites was considered in setting the final dredging rates for the FS (e.g., the case studies in the *Sediment Technologies Memorandum*).

### Master Comment 8.19

A commenter argued that since PCBs were discharged in a dissolved/emulsion form they continue to partition between water and sediments, which causes dispersal and minimizes “hot spots” (vs. pure-phase discharged to the Hudson River, for example).

### *Response*

WDNR and EPA disagree with this assessment. Furthermore, it is not relevant what phase the PCBs are in when discharged into the River. The RI identifies numerous deposits of soft sediment with elevated PCB concentrations. PCBs continue to pose an unacceptable risk and are continuing to bioaccumulate in fish.

## 8.3 Dredge Material Disposal

### Master Comment 8.20

Commenters offered the observation that if placing contaminated sediment into a landfill met serious public resistance, potentially sediment would have to be shipped out of state for disposal, causing costs to be prohibitive. The commenter further stated that no options for siting the pipeline or selecting preferred/recommended routes for conveyance of dredged sediment were included in the FS and that trucking is prohibitive if pipeline siting cannot be agreed upon.

### *Response*

The WDNR agrees that the tipping and transportation costs would be costly if dredged sediments had to be transported and disposed of out of state. However, recognizing the passage of resolutions by almost every city council and county board in the Fox River Valley supporting a local solution to the problem, WDNR and EPA do not see this scenario playing out. Local landfills with sufficient capacities exist. Furthermore, there is interest by local landfills to contract for the disposal of these sediments as they represent a secure stable waste stream and business opportunity for a longer period of time. With the purchase of the abandoned railroad right-of-way for the Fox River Trail, the option of locating a pipeline to transport dredged sediments to potential landfill sites in the Town of Holland area is completely feasible. The state had the foresight to negotiate use of the trail’s right-of-way; locating another route for the pipeline would have been difficult, time intensive, and costly.

The WDNR also agrees with the statement that a local solution is critical to keeping costs down.

## Master Comment 8.21

A commenter suggested that lime, used for stabilization of dewatered sediments, was not factored into the disposal sediment tonnage estimate.

## *Response*

As part of the pre-design testing for the pilot dredging project at SMU 56/57, bench-scale solidification tests were conducted to evaluate the performance of various additives for solidification. Based on the bench-scale solidification test results, it is apparent that a 10 percent by wet weight high-calcium pebble lime mix results in almost no increase in total weight after solidification. This is attributed to the water vapor loss caused by heat of hydration ($CaO + H_2O$) when lime is mixed with wet sediments.

It should also be noted that lime addition is not necessarily needed. During the 2000 dredging project at SMU 56/57, the dredged sediments did not need any further stabilization (no lime was added) to be acceptable for disposal. Therefore, it is not necessary to include additional tonnage into the disposal estimates.

## Master Comment 8.22

A commenter, Minergy Corporation, provided detailed information on the status of the an update on the status of the GFT feasibility project being conducting by the company in cooperation with WDNR, the EPA Superfund Innovative Technology Evaluation (SITE), and EPA Great Lakes National Program Office (GLNPO). Minergy indicated this technology was an appropriate thermal treatment technology that should be considered in the FS. The GFT information included:

- Expected emissions from a full-scale operation would be very low, including a stack-basis destruction of PCBs of greater than 99.9999 percent.

- The annual PCB emissions in the stack would equate to 1.58 grams per year or 0.0035 pounds per year. This is only 3.5 percent of the WAC Section NR 445 Table 3 values for PCB emissions. Therefore, no additional study for the economic and technical feasibility for additional controls will be necessary at this emission level.

- The GFT provided net destruction of dioxin. Dioxin (2,3,7,8-TCDD) was not detected in the final exhaust after the air quality control equipment. Some dioxin/furans were detected in the exhaust gases prior to the air quality control equipment; however, they were clearly present in the sediment.

- Treatment of the sediment is cost-effective. Unit costs were estimated to be between $25 and $50 per ton of dewatered sediment (50 percent solids), which are less than the disposal costs from both pilot dredging projects.

### *Response*

WDNR and EPA agree that GFT is potentially a feasible alternative for management of dredged material. Based on the information submitted documenting the results of the pilot-scale testing of the GFT, WDNR modified text within the FS to incorporate this technology (and the results of the pilot project). GFT was then carried forward in the FS as the representative process option for thermal treatment of sediment in lieu of high-temperature thermal desorption (HTTD). Cost estimates were revised for this alternative based on this information.

### Master Comment 8.23

Commenters expressed concern that the Proposed Plan presentation is difficult to comment on. For instance, the reference to an unnamed landfill and the use of some kind of public right-of-way to run a pipeline from the Lower Fox River to the landfill seem intentionally vague.

### *Response*

WDNR and EPA believe that the level of detail presented in the Proposed Plan and accompanying FS are appropriate for this point in the project process. Identification of the actual landfills accepting the sediment, transportation routes for either trucks or a pipeline are issues that are to be addressed in the remedial design phase of the project following issuance of the ROD.

### Master Comment 8.24

Commenters indicated their preference that PCB hotspot sediments with higher concentrations be detoxified permanently using non-incineration, closed-loop technologies.

### *Response*

The FS evaluated over 100 different technologies that could be applied to remediation of the Lower Fox River sediments. Of the technologies evaluated, there were no applicable and practical technologies that would allow for detoxification using non-incineration, close-looped technologies. WDNR and EPA duly note the commenter's preference of both treatment of the more highly contaminated sediments and closed-loop non-incineration technology.

## Master Comment 8.25

Commenters recognized and accepted that a large volume of landfill space will be necessary to dispose of the lower-concentration PCB-contaminated sediments dredged from the River and Bay. They further stated that these landfills must be state-of-the-art landfills in full compliance with state and federal laws.

## *Response*

The WDNR and EPA agree with this comment. Any landfill accepting contaminated sediment from the Lower Fox River will be licensed under applicable state and federal laws.

## Master Comment 8.26

Commenters recognized and accepted the necessity for a sediment slurry pipeline to transport dredge spoils to landfill disposal sites.

## *Response*

The WDNR and EPA agree with this comment.

## Master Comment 8.27

Commenters indicated their preference for closed-loop PCB destruction technologies and their use for sediments with greater than 50 ppm PCBs. They favored the Eco-Logic process citing that burning, melting, or incineration technologies must not be used due to the likely formation of dioxins and furans and the high potential for release of co-contaminants (mercury and lead).

## *Response*

Data generated by the EPA Superfund Innovative Technology Evaluation program shows that thermal treatment technologies like vitrification do not generate dioxins and furans in the off gases from these technologies. Further, WDNR and EPA do not agree with the commenters' assertions that properly engineered and operated pollution control equipment does not reduce emissions of heavy metals to regulated levels.

## Master Comment 8.28

Commenters offered that WDNR and EPA should not assume the availability of local landfill capacity.

### *Response*

Landfills with sufficient capacities exist in close proximity to the Lower Fox River. Furthermore, there is interest by local landfills to contract for the disposal of these sediments as they represent a secure, stable waste stream, cash flow, and business opportunity for a long period of time. WDNR and EPA also recognize the passage of resolutions by almost every city council and county board in the Fox River Valley calling for and supporting a local solution to the problem. Thus, WDNR and EPA believe that the facility can be located, consistent with the assumptions used for evaluation of the selected remedy in the ROD.

## Master Comment 8.29

Commenters noted that the most cost-effective means of landfilling dredged sediments may involve the siting and construction of a new landfill. The commenter is concerned that this key issue could significantly delay the remediation plan. Another commenter noted that the treatment and disposal of sediments will require development of substantial infrastructure, which will restrict productivity and extend the dredging project timeline.

### *Response*

The dredging, treatment, and disposal of sediments will require a substantial infrastructure and timeframe to in place for the management, treatment, dewatering, and disposal of dredged sediments. The WDNR recognizes the key to making this all come together relies on several factors:

- Contracting with qualified/competent contractors with the experience and proven track record in conducting projects of this magnitude. (The WDNR witnessed the importance of this in its two demonstration projects.)

- Successfully negotiating with existing licensed local public and private landfill owner/operators for disposal of the sediments. Utilizing existing landfills or ones that are partially through the siting process will expedite sediment disposal. (The WDNR has been approached by different area landfills with an interest in taking sediments. Similarly, members of the FRG that have landfills may offer disposal capacity as part of their settlements, similar to what Fort James did in the SMU 56/57 demonstration project.)

- Dedicating WDNR plan review staff to expedite plan reviews linked to the Lower Fox River to ensure permits and licenses are issued in a timely manner.

- Managing the overall River cleanup in smaller, more manageable units. (The timeframe for completing the removal and/or capping of the sediments spans more than a decade.) Staging dredging and capping projects accordingly can develop the needed infrastructure over time.

- Successful management and oversight to ensure contractors and consultants are meeting project and contract expectations.

The same concerns are applicable to capping or any other remedial approach to an environmental project of this size.

### Master Comment 8.30

A commenter noted that with construction of a pipeline, there are necessary institutional and community concerns. They recommend that WDNR initiate planning for this issue jointly with efforts for establishing a viable landfill location(s) as soon as possible.

### *Response*

WDNR and EPA agree with this comment and plan to utilize an experienced expert technical review team to further assess the planning, operation, and construction of the pipeline and disposal facility.

### Master Comment 8.31

A commenter offered their preference to use innovative technologies for treatment so as to minimize landfilling of contaminated sediment.

### *Response*

Comment noted.

## 8.4 Safety Concerns and Community Concerns

### Master Comment 8.32

Commenters felt that sediment handling and treatment is as crucial as proper removal and urged the WDNR to take appropriate precautions to control volatilization.

## *Response*

Based on the results of the air monitoring conducted during the dredging project at SMU 56/57 (WDNR, 2000), volatilization of PCBs to the atmosphere are not likely to be a risk to the surrounding communities. Clearly, during remediation of the most highly contaminated sediments in the entire Lower Fox River, volatilization did not reach a level that posed a risk to human health. The FRG (BBL, 2000) concluded that: "Although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions and resulting concentrations were found to be relatively small and insignificant relative to human exposure and risk." The highest concentration recorded on site is less than 80 percent of the conservative risk level while off-site risks never exceeded 4 percent. In any case, the identification and use of control measures to minimize volatilization will be addressed during the remedy design activities following issuance of the ROD.

### References

BBL, 2000. Major Contaminated Sediment Site Database. Last updated August 1998. Website. http://www.hudsonwatch.com.

WDNR, 2000. *Post-Dredging Results for SMU 56/57*. Memorandum prepared by Bob Paulson. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 21.

## Master Comment 8.33

A commenter observed that significant questions exist as to the feasibility of massive dredging such as whether equipment can be staged in appropriate areas and whether disposal sites will be available. The commenter suggested that the FS and Proposed Plan contain no analysis of the feasibility of the proposed twin 28-mile slurry pipeline, including permitting and the likely local opposition to a pipeline that could carry dredged slurry through residential areas.

## *Response*

For the purposes of the FS, potential locations were identified based on screening-level field observations from an engineering perspective. In the FS, it was necessary to identify potential locations of support facilities to analyze equipment requirements, and develop conceptual engineering plan and cost estimates for the remedial alternatives. The locations selected in the FS are representative of reasonable assumptions with regard to distance from the dredging work and related costs. The final location(s) of these facilities will be determined during the project's design stage. Additional analyses will be performed to determine more information about the proposed facilities and public comment/input will be considered in the final facility sitting decision.

## Master Comment 8.34

Commenters noted that limited River access, high truck traffic, residual sediment PCB concentration, and treatment requirements will make a full-scale dredging project difficult, prolonged, and costly; equipment would have to be transported by truck to get an adequately large dredge to the Site (a small dredge would not reach depth, temporarily exposing high concentrations).

### *Response*

There are several points to this comment. First of all, these issues are germane whether a dredging or a capping plan were selected. For both options, truck traffic, River access, residual surface concentration, equipment transportation, etc., are also important considerations that need to be dealt with. In one case, large quantities of material are brought to the River and that material needs to be spread on the River bottom and in the other scenario, material is removed from the River bottom and has to be taken off-site.

## Master Comment 8.35

Commenters noted that the public should be informed that the Proposed Plan would cause significant noise, intrusive artificial lighting, and stress on existing transportation systems. The commenters noted that all reasonable steps should be taken to minimize the negative impacts of remediation on host communities including noise control, limited nighttime light pollution, the use of a pipeline rather than truck transportation, and minimization of outdoor material handling.

### *Response*

WDNR and EPA agree with the commenter that impacts to communities where staging of the remedial action or disposal of the sediment is to occur should be minimized to the extent practicable. The Agencies believe that this can be accomplished given the successful completion of dredging projects at both Deposit N and SMU 56/57. Community relations and concerns will be addressed during design of the remedy, following issuance of the ROD.

## Master Comment 8.36

Commenters felt that the Proposed Plan failed to address onshore contamination concerns of shoreline property owners.

### *Response*

Given the geographic and topographic features of the Lower Fox River, there are no large floodplain areas. In a few cases, small amounts of dredged material from the River have been used as fill in upland areas. In these cases, the residual PCB contamination is being addressed as part of the site-specific upland investigation and remediation. In Green Bay, concentrations within the Bay do not appear to be sufficient to create shoreline contamination at levels of concern. Based on limited sampling, there have been no indications that the shoreline is contaminated. Furthermore, this observation is inconsistent with the nature of the industrial processes that caused contamination in the River (discharge of wastewater).

## Master Comment 8.37

A commenter offered that, in their opinion, the dredging schedule currently requires around-the-clock trucking to transport dewatered sediments from OU 1, causing serious traffic density, highway safety, and aesthetics issues.

## *Response*

WDNR and EPA disagree with the opinions offered by the commenter. Three dredging projects (the ongoing navigational dredging, the Deposit N project, and the SMU 56/57 project) have been successfully completed on the Lower Fox River that did not encounter any of the problems the commenter cites. Further, at the dredging projects at Deposit N and SMU 56/57, trucking was not required around the clock to effectively remove the sediments to the landfill. These issues are more appropriately resolved during remedial design following issuance of the ROD.

## Master Comment 8.38

Commenters offered that PCBs will volatilize to the air, but the Proposed Plan fails to account for this in its analysis of the protectiveness or effectiveness of dredging. The commenters suggested that although PCBs are highly hydrophobic chemicals that, when placed in aquatic environments, tend to become sorbed to organic matter and sediment, a very small portion of the PCB mass in an aquatic system exists in the water column, either adsorbed to water column organic matter or in a freely dissolved state. Some portion of freely dissolved PCBs can volatilize into the atmosphere.

## *Response*

As demonstrated by WDNR’s Urban Air Toxics Monitoring (WUATM) program, atmospheric levels of PCBs are already elevated in the Green Bay area. These findings were confirmed during the GBMBS where researchers estimated that during the 1989/1990 study period, approximately 154 kg of PCBs volatilized from the surface of Green Bay. Further, an additional 24 kg were estimated to have volatized from the surface of the Lower Fox River. Although elevated PCB levels have been documented, as illustrated in the BLRA, these levels do not pose an unacceptable risk.

Air concentrations of PCBs were also monitored during the dredging project at SMU 56/57 (WDNR, 2000). The general design of the project deployed samplers along a grid surrounding the project site and work areas to collect samples for spatial analysis. The grid was intended to provide upwind and downwind locations for each sampling event. Monitoring was conducted throughout the duration of the 2000 dredging project. An outer ring of samplers was established approximately 2 km from the project site while a second inner ring was located approximately 1 km away. The remaining samplers were deployed 250 and 500 meters from the center of the project site. The closest samplers were on the project site, directly adjacent to both the dewatering basins and presses. A conservative ambient level of concern was established at 100 $ng/m^3$, which equates to a $10^{-5}$ cancer risk.

Ambient concentrations observed during the 24-hour sampling regime ranged from less than 0.2 $ng/m^3$ to 79.7 $ng/m^3$ during the dredging and sediment processing. Ambient concentrations within the property boundaries of the remediation area ranged from approximately 0.7 $ng/m^3$ to 79.7 $ng/m^3$ while off-property concentrations reached a maximum of only 3.6 $ng/m^3$. The highest concentration recorded on site is less than 80 percent of the conservative risk level while off-site risks never exceeded 4 percent.

Clearly, during remediation of the most highly contaminated sediments in the entire Lower Fox River, volatilization did not reach a level that posed a risk to human health. The FRG (BBL, 2000) even concluded that: "Although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions and resulting concentrations were found to be relatively small and insignificant relative to human exposure and risk."

As stated above, remediation at SMU 56/57 removed the most highly contaminated sediments in the entire River. Based on the reported mass (654 kg) and *in-situ* sediment volume removed (31,500 cy), sediments at SMU 56/57 averaged 20.8 grams per cubic yard (g/cy). In contrast, the Proposed Plan averages only 4 g/cy (29,259 kg/7.25 million cy). Even if one assumes a volatilization rate equal to that observed during the dredging project, the sediments to be handled during the entire remediation are less than one-fifth as concentrated, so the mass of PCBs lost during the entire remediation period (125 kg) would be less than that estimated for just 1989/1990 during the GBMBS (154 kg).

### References

BBL, 2000. Major Contaminated Sediment Site Database. Last updated August 1998. Website. http://www.hudsonwatch.com.

WDNR, 2000. *Post-Dredging Results for SMU 56/57*. Memorandum prepared by Bob Paulson. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 21.

## Master Comment 8.39

Comments were submitted that listed several concerns regarding volatilization of PCBs into the air and the commenters' opinion that this issue is a seriously neglected concern regarding human health. The commenters offered that volatilization should be prevented, to the extent practicable, through enclosing all sediment processing and wastewater treatment systems, including handling, transport, and landfill systems.

### *Response*

WDNR and EPA recognize the potential loss of PCBs through atmosphere during removal, handling, and disposal of River sediments. However, the identification, use, and implementation of control measures to minimize volatilization is more appropriately addressed during the remedy design activities following issuance of the ROD. In addition, air monitoring will be incorporated into the various on-water and upland activities during implementation to address community and workers' concerns.

Recognizing the results of the air monitoring conducted during the dredging project at SMU 56/57 (WDNR, 2000), the Agencies have determined that activities associated with implementing the Proposed Plan will not result in unacceptable risk as a result of PCB losses to the atmosphere. Ambient concentrations observed during the 24-hour sampling regime ranged from less than 0.2 ng/m$^3$ to 79.7 ng/m$^3$ during the dredging and sediment processing. Ambient concentrations within the property boundaries of the remediation area ranged from approximately 0.7 ng/m$^3$ to 79.7 ng/m$^3$ while off-property concentrations reached a maximum of only 3.6 ng/m$^3$. The highest concentration recorded on site is less than 80 percent of the conservative risk level while off-site risks never exceeded 4 percent. Sampling adjacent to the landfill accepting the dredge material from SMU 56/57 indicated that 29 of 31 samples had no detectable PCBs. The two samples that did show detectable PCBs were not significantly different from background samples also collected in the area.

Clearly, during remediation of the most highly contaminated sediments in the entire Lower Fox River, volatilization did not reach a level that posed a risk to human health. The FRG (BBL, 2000) even concluded that: "Although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions and resulting concentrations were found to be relatively small and insignificant relative to human exposure and risk."

As stated above, remediation at SMU 56/57 removed the most highly contaminated sediments in the entire River. Based on the reported mass (654 kg) and *in-situ* sediment volume removed (31,500 cy), sediments at SMU

56/57 averaged 20.8 g/cy. In contrast, the proposed remedial plan averages only 4 g/cy (29,259 kg/7.25 million cy). If one assumes a volatilization rate equal to that observed during the dredging project, the sediments to be handled during the entire remediation are less than one-fifth as concentrated and therefore the mass of PCBs lost during the entire remediation period (125 kg) would be less than that estimated for just 1989/1990 during the GBMBS (154 kg).

### References

BBL, 2000. Major Contaminated Sediment Site Database. Last updated August 1998. Website. http://www.hudsonwatch.com.

WDNR, 2000. *Post-Dredging Results for SMU 56/57*. Memorandum prepared by Bob Paulson. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 21.

# 9 Selection of Remedy

## 9.1 General Comments

### Master Comment 9.1

Commenters stated that a reduction of PCB mass does not necessary cause equivalent reduction in exposure or risk to biota and that dredging may disperse buried PCBs increasing short-term risk. The commenters go on to say that risk reduction should be the ultimate goal of any sediment management activity.

### *Response*

WDNR and EPA agree that risk reduction should be the ultimate goal of any sediment remediation project whether that activity is a MNR, capping or removal program. However, the remedy selected for OU 1 is not a mass removal activity. The selected remedy is risk based in that the residual SWAC based on the RAL of 1 following remediation will result in significant risk reduction. The Agencies also realize that active remediation will result in a small (2.2 percent) amount of resuspension of contaminated sediments. Furthermore, if no action is taken in OU 1, then there will continue to releases of PCBs from contaminated sediment.

### Master Comment 9.2

Commenters stated that background conditions and technical impracticability will frustrate achievement of fish tissue concentrations for high-intake consumers because background levels in Lake Winnebago fish tissues result in fish consumption advisories. The commenters also stated that atmospheric PCB deposition contributes to background concentrations.

### *Response*

The commenters are correct in that fish consumption advisories exist for Lake Winnebago. These advisories however are less stringent than those for the Lower Fox River and Green Bay. For instance in Little Lake Butte des Morts and the rest of the lower Fox River, all sizes of carp are “Do Not Eat” and there are no species of fish that can fall into the “unlimited” or “once per week” consumption categories. However, the Lake Winnebago advisories allow for much more frequent consumption of most species (“unlimited” or “once per week”) and only limit large carp and large channel catfish consumption to 12 meals to year. There are no “Do Not Eat” or “Eat no more than six meals per year” restriction in Lake Winnebago.

The Agencies agree that atmospheric deposition contribute to background concentrations.

## Master Comment 9.3

Commenters indicated that dredging 8.95 million cy of sediment from the Lower Fox River which removes two-thirds of total volume of sediment in the River is not the right solution.

## *Response*

The Proposed Plan does not recommend removal of 8.95 million cy of material. The plan calls for the removal of approximately 7.25 million cy. Regardless, based on careful consideration of all data and an evaluation using the nine evaluation criteria in the NCP, WDNR and EPA have determined that removal and disposal of approximately 780,000 cy of contaminated sediments in OU 1 is protective, implementable, and cost-effective. Sediments in OUs 3 through 5 will be considered in another ROD.

## Master Comment 9.4

Commenter stated that when using different models, the remedy from the Proposed Plan does little to reduce projected human health risks and that changes to numerical risk estimates are minor and are not significant, given the uncertainty of the analysis.

## *Response*

WDNR and EPA disagree with the foundation of this statement; that the models used in the RI/FS are flawed. Over the years, WDNR has worked cooperatively and collaboratively to develop the models that can be used as a tool to assist in decision making on this project. The Agencies' primary model is wLFRM. This model was initially developed as part of the Green Bay Mass Balance Study (GBMBS) as part of a suite of coupled water quality models describing PCB transport in the Lower Fox River and Green Bay were developed. Since the end of the GBMBS, efforts to examine and assess the performance of Lower Fox River water quality models have continued. Four generations of water quality model development have been initiated. The model developed as part of RI/FS efforts is the result of continued assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. To distinguish this model from prior generations of development, this fourth generation model is identified as the "whole" Lower Fox River model (wLFRM).

Development of the wLFRM was based on the results of a 1997 agreement and a peer review of model performance with the Fox River Group (FRG). A component of the agreement was to evaluate water quality models for the Lower Fox River and Green Bay with the intent of establishing goals to evaluate the quality of model results and a Model Evaluation Workgroup was formed. The Workgroup was comprised of technical representatives for the FRG and WDNR in order to undertake "cooperative and collaborative" evaluations of model performance. Development of a series of technical reports followed. The series of reports developed by the Workgroup were each prepared as a Technical Memorandum (TM) and are included in the Model Documentation Report. . The TMs provide detailed analyses of key aspects of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions.

In addition to the Workgroup efforts, a peer review panel presented additional assessments of model performance. To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts. The wLFRM describes PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the River mouth at Green Bay in a single spatial domain.

More information on wLFRM development can be found in the Model Documentation Report which was prepared as a supporting document to the RI/FS and in *White Paper No. 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study and Proposed Remedial Action Plan*.

The models used to support these claims do not appear to have been subject to same degree of scientific scrutiny and peer review as was wLFRM. WDNR did review the FOXSIM model and the conclusions of that review can be found in *White Paper No. 15 – FoxSim Model Documentation*.

More information on how the Agencies used the models in making our decision can be found in *White Paper No. 9 – Remedial Decision-Making in the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study and Proposed Remedial Action Plan.*

## Master Comment 9.5

Commenters stated that mass removal of PCB-contaminated sediment will improve the health of the ecosystem and provide greater protections for public health.

## *Response*

WDNR and EPA have chosen a remedial approach based on risk reduction. Given the circumstances of the Lower Fox River, this approach also results in the significant PCB mass removal.

## Master Comment 9.6

A commenter suggested that the local governments support an immediate and intensive negotiation process to provide the funding and other commitments necessary to allow remedial action to commence promptly.

### *Response*

WDNR and EPA will have discussions with PRPs concerning their implementation of the selected remedy. Any local support that can expedite implementation of the remedy is appreciated.

### Master Comment 9.7

A commenter offered that cleanup work must begin as soon as possible. The commenter wanted multiple dredging crews working simultaneously at several sites along the River and in the Bay to ensure the cleanup progressed as quickly as physically possible.

### *Response*

WDNR and EPA would also like to see active in-water remediation take place quickly. Toward that end, WDNR and EPA have conducted the pilot projects to demonstrate that dredging can be done on the River in an effective fashion with minimal disruption of industry or the community. While the ROD only determines a cleanup plan for OU 1, it is recognized that expediting activities in OU 1 and possible work in other OUs is highly desirable.

### Master Comment 9.8

A commenter observed that natural and anthropogenic forces acting on the River and the Bay, the permanence of any solution, and the need for long-term monitoring should all be considered when evaluating remediation options.

### *Response*

WDNR and EPA agree with this comment and believe these items have been considered in the selection of a remedial alternative.

### Master Comment 9.9

Commenters stated that PCBs will remain toxic for centuries and there are no guarantees about the future stability of human society in this area considering how much has changed in the past 150 years.

### *Response*

PCBs are very persistent, are readily passed along in the food chain, and will continue to pose human health and ecological for years to come. The Agencies believe the most effective way to permanently address this situation is to reduce or eliminate the exposure pathway through the implementation of the selected remedy for OUs 1 and 2. This will involve active removal of contaminated sediments, where necessary, to achieve the risk reduction and to appropriately managed the dredge materials in such a way that they do not pose a threat. Landfilling of dredged material is an effective way to isolate those materials.

# 9.2 Cost

## Master Comment 9.10

Commenters wrote that the PCB problem has been stated too generically, with inadequate precision to lead to a technically appropriate, cost-effective solution.

### *Response*

In preparing the RI/FS, the Proposed Plan, and the ROD, WDNR, with assistance from EPA, followed all the appropriate guidance for completing these documents. The level of detail afforded these documents is consistent with what guidance says for this juncture of the Superfund process. At this point, cost estimates are expected to be within -30 and +50 percent. It is important to recognize that this is the point where WDNR and EPA are selecting an option, not formally adopting a fully designed engineering remediation plan. With the completion of the ROD, WDNR and EPA will proceed with negotiation of a Consent Decree with the responsible parties at which time a detailed engineering design will be completed.

## Master Comment 9.11

Commenters stated that the cost of the dredging identified in the Proposed Plan is seriously underestimated and misleading and that other alternatives would cost less. The three new alternatives cost less than the remedy proposed in the Proposed Plan as they address less sediment volume.

### *Response*

WDNR and EPA strongly disagree with the comment, which states that the cost estimates proposed for dredging in the Proposed Plan is underestimated and misleading. The detailed cost estimate for Lower Fox River and Green Bay presented in Appendix H of the FS was developed based on cost estimates from previous projects for dredging. Landfill capacity, costs, and disposal costs in Wisconsin were determined and included in the cost estimates. WDNR and EPA also believe that a local solution is a key to keeping costs from increasing.

As stated in Appendix B of the FS, the total dredging cost per cubic yard for 17 projects reviewed ranged from approximately $6 to $507 per cy. The dredging cost per cubic yard generally decreased as the volume of sediment to be removed increased (regardless of removal method). It is apparent that the dredging unit costs developed in the FS are within the range of the unit costs represented by the 17 projects. Also, implementation at projects like Oakland Harbor was performed at unit costs comparable to the costs in the FS.

## Master Comment 9.12

Commenters expressed their position that the total estimated cost of approximately $300 million is a reasonable expenditure that will reap significant environmental benefits.

### *Response*

The Agencies agree that the costs estimated are reasonable and will provide a protective remedy with significant benefits. As part of WDNR's and EPA's evaluation of comments on the RI/FS and Proposed Plan, the costs associated with the 1 ppm cleanup level were reviewed again. The cost estimate to implement the remedy is now estimated at $76.10 per cy. This is within a small percentage of the amount in the Proposed Plan. WDNR and EPA believe that the cost of conducting the remediation and monitoring activities are within Superfund guidance criteria of -30 to +50 percent for purposes of cost estimations. For the phase WDNR and EPA are at in the Superfund process, this is an acceptable range per federal Superfund guidance. It is quite likely that this money will have a direct positive effect on the local economy.

## Master Comment 9.13

Commenters noted that there are benefits associated with moving forward with the cleanup, and stated that remediation is a good investment and that delays could reduce the effectiveness of the remediation effort with no reduction in cost now.

### *Response*

WDNR and EPA agree. Moving forward with remediation in the River will begin to reduce the risks and result in a lower overall cost compared to delaying action. However, WDNR and EPA are constrained by legal and administrative requirements that laws and regulations require be observed.

## Master Comment 9.14

Commenters stated that WDNR should do whatever possible to create a sense of certainty relating to the proposed costs of remediation for the Lower Fox River and Green Bay.

### *Response*

In preparing the cost estimates included in the FS, WDNR and EPA followed the appropriate guidance for completing these estimates found in Appendix H of the FS. The level of detail is consistent with guidance, which calls for cost estimates to by within -30 and +50 percent. It is important to recognize that this is the point at which WDNR and EPA are selecting an option, not formally adopting a fully designed engineering remediation plan. With the completion of the ROD, WDNR and EPA will not proceed with negotiation of a Consent Decree with the PRPs at which time a detailed engineering design will be completed. A detailed design will allow for more detail in cost estimates.

## Master Comment 9.15

Commenters stated that the approach in the RI/FS is faulty because it incorporates an open-ended settlement with the PRPs and that this approach will maximize adverse economic impacts and create uncertainty regarding the final cost to area companies, and therefore strongly supports a “sum certain” settlement of this matter.

### *Response*

Selection of a remedy for a site is based on its protection of human health and the environment. WDNR and EPA do consider the cost effectiveness of a remedy when choosing that remedy. That is, WDNR and EPA chose the remedy that will provide the needed level of protection for the least amount of money. The remedy for this Site is large and thus is very expensive, and as with any construction project, the costs will have uncertainty.

However, in negotiating the implementation of the remedy, the Agencies will consider several factors. First, WDNR and EPA always look at a company’s ability to pay for the remedy or its share of the remedy. It is never the intent of WDNR or EPA, or in its interest, to cause serious economic disruption to a company’s operations. A company isn’t required to pay more than its ability to pay. Also, WDNR and EPA do and in this case will, consider cash-out settlement with companies. Companies that want the certainty of costs can approach the WDNR and EPA to see if the payment of a specific amount in a specific timeframe can be agreed upon.

It should be noted that the work would bring some economic benefits to the communities, with an influx of money in the form of living expenses of construction crews, local purchase of work-related materials, and subcontracting opportunities for local firms. There would also be economic benefits to the region related to environmental improvements. These would include tangible (e.g., restoration of commercial fisheries, decreased costs for navigation dredging, and increased tourism revenue), and intangible (e.g., quality of life and area “image”) benefits.

## Master Comment 9.16

Commenters noted that the paper industry represents 40 percent of the manufacturing base and is the single most important constituent of the regional economy. In addition, the area has experienced some economic dislocation (e.g., paper companies leaving the area).

### *Response*

While there have been changes to the paper businesses in the Fox River Valley, these changes are not related to the proposed remediation of the River. Paper companies have never come to the WDNR or EPA and presented any written their evidence or stated at meetings that the cost to do this work is a factor in any of their business transactions, such as plant closing or layoffs in the Fox River Valley. Many of these business transactions have taken place at paper facilities that are not PRPs. It is the interest of the state and EPA that the Fox River Valley remains a strong economic base for the State of Wisconsin. WDNR and EPA do not anticipate this remediation creating economic problems. Please see *White Paper No. 17 – Financial Assessment of the Fox River Group*.

### Master Comment 9.17

Commenters stated that the cleanup plan for the Lower Fox River and Green Bay should significantly reduce the human health risks and ecological risks without concern for what the PRPs can afford.

### *Response*

WDNR and EPA believe that the remedy will significantly reduce risks in the Lower Fox River. This is discussed previously in the sections of this Responsiveness Summary dealing with risk and selection of the remedial action level. In addition, and as is stated above, the Agencies do consider several factors in negotiating with the PRPs and one of those factors is the company's ability to pay for the remedy or its share of the remedy. The Agencies are concerned with the economic health of the companies and the Fox River Valley. It is never the intent of WDNR or EPA, or in its interest, to cause serious economic disruption to a company's operations. WDNR and EPA don't require a company to pay more than its ability to pay. Also, WDNR and EPA do and in this case will, consider cash-out settlement with companies. Companies that want the certainty of costs can approach the WDNR and EPA to see if the payment of a specific amount in a specific timeframe can be agreed upon.

### Master Comment 9.18

A commenter noted that people are concerned about the project costs, but they should compare these costs with other costs such as the new Packer Stadium – $1,272 per resident.

### *Response*

Comment noted. It is the intent of the Agencies that the PRPs pay for the remediation, not taxpayers. However, WDNR and EPA also believe that a local solution, supported by local units of government, is one of the keys to keeping costs from increasing.

### Master Comment 9.19

What are the health and medical care costs due to the current over-exposure to PCBs? And would a cleanup significantly reduce these costs? If we assumed that the associated costs due to exposure were one-half of 1 percent of the lifetime cost, that would come to $8,126,000,000 which is well over the cost of the project.

### *Response*

The costs of health and medical care due to PCBs in the Lower Fox River are outside the scope of the RI/FS and BLRA.

### Master Comment 9.20

Commenters expressed concern that long-term stewardship (similar to financial responsibility for landfills) should be required via performance bonds, irrevocable trusts or escrow accounts, insurance, or guarantees of net worth to accommodate any necessary remediation or perpetual care after rehabilitation is complete. Commenters also stated that long-term monitoring and maintenance costs over several centuries could easily exceed the short-term costs of a permanent solution (the PCBs and other toxic chemicals will not break down).

### *Response*

The remedial action plan selected for each OU of the River will include performance measures and monitoring to assure that it achieves and maintains the cleanup goal. While the financial responsibility for landfills (i.e., WAC NR 520) would not be applicable for such cleanup activities as capping sediments, the WDNR does have the authority to require financial responsibility to pay for monitoring and long-term care of this type of project. Projected costs for long-term monitoring as well as contingency plans for maintenance and repair of the capping material would be included in the remedial action plan. In the event a cap would be placed in a portion of the River, the WDNR and EPA would also examine the need for further fiduciary responsibilities for the PRPs for long-term cap monitoring and maintenance.

## 9.3 Long-Term Monitoring

### Master Comment 9.21

Some commenters believe that the draft Model Long-term Monitoring Plan (LTMP) included in the FS is overbroad and inconsistent with the NCP. In addition, some commenters believe that a simpler and effective monitoring plan should take into account the absence of other feasible remedial alternatives for the Bay; eliminate Zone 4 monitoring, eliminate bird tissue/eagle egg/blood plasma monitoring and limit monitoring to PCB trends in fish; eliminate observational surveys of mink habitat (already well characterized); and use data from existing monitoring programs whenever possible to avoid duplication of effort.

## *Response*

WDNR and EPA believe that the draft Model LTMP is compliant with the NCP. The LTMP is consistent with the NCP in that it was developed as part of the Feasibility Study to confirm the effectiveness of the selected remedy to reduce risk to receptors from PCBs as well as other contaminants of concern. The LTMP is to be implemented for all OUs and will be modified in the remedial design stage to be consistent with the remedy selected for each individual OU.

The draft Model LTMP was drafted based upon a thorough and careful review of existing state, regional, and national monitoring programs. In addition, the LTMP took into consideration direct input from the resource agencies in the states of Wisconsin and Michigan, EPA, USFWS, NOAA, and the independent Menominee and Oneida nations. These resource agencies determined that given the magnitude of the PCB contamination in Green Bay, an MNR alternative could not be selected as the remedial alternative without a comprehensive, bay-wide program that monitors all important species, not just fish.

## Master Comment 9.22

The comments submitted by the API Panel included recommendations for monitoring surface water, sediments, fish, and physical measurements of the River bottom and cap. They also offered that these monitoring elements need to be included the financial/institutional structure for operations and maintenance of all remedy components.

## *Response*

The LTMP prepared by the API Panel appears to incorporate some of the same elements that are included in the draft Model LTMP developed as part of the FS. However, the API Panel’s LTMP is sparse; both in terms of detail (e.g., fish species, age of fish, number of sediment samples, water samples), as well as in terms of the adequacy of sampling relative to the size of the proposed capping area. The API Panel’s LTMP also does not include any reference to LTMPs developed and implemented at other cap sites (e.g., Eagle Harbor, Simpson Tacoma, Duwamish Waterway), or for that matter within the ARCS guidance documents. All of these plans incorporate sediment sampling, that evaluate contaminant migration or advective or diffusive flux, and native visual examination of the cap's physical integrity. The API Panel lists sediment sampling, but does not explain how they will collect samples from under the rock armored layer. *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* lays out the monitoring program for the *in-situ* capping that would be needed to monitor successful isolation for the Lower Fox River.

## Master Comment 9.23

The API Panel suggested that the LTMP should focus on primary COCs (PCBs, mercury, DDE), but also consider additional COCs, with a final list developed in the final stages of remedy design. The API Panel also suggested that cores should be collected from the cap at 5 years and every 10 years.

## *Response*

WDNR and EPA agree with many of the commenters' suggestions if a cap is chosen as part of the final remedy. However, the Agencies do not agree with the schedule proposed by the API Panel and believe more frequent monitoring of the cap is necessary to assure the integrity of the cap. A 10-year interval is not an acceptable frequency.

The general elements of the cap monitoring plan in the FS followed that described by Palermo et al. (1998), and relied specifically on the detailed monitoring plans developed for the Simpson Tacoma Cap, West and East, and West Eagle Harbor Superfund sites in Washington, and the Soda Lake Monitoring Plan in Casper, Wyoming. In each of those monitoring plans, sampling and analysis are more intensive in the first 5 years following construction, and thereafter decrease in frequency only if the cap integrity is maintained as expected. For example, core samples are collected through the cap into the underlying contaminated sediments every year for the first 5 years post-construction. Sections are taken from the core in order to determine if any migration of underlying contaminants has occurred. Specific operations and maintenance actions are tied to the presence of contaminants in order ensure permanent isolation of the contaminant(s). The plan presented in the FS is consistent with the plans listed and is very similar to that proposed by the API Panel. See also *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* for additional discussion.

### Reference

Palermo, M. R., J. E. Clausner, M. P. Rollings, G. L. Williams, T. E. Myers, T. J. Fredette, and R. E. Randall, 1998a. *Guidance for Subaqueous Dredged Material Capping. Technical Report*. DOER-1. United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. Website: http://www.wes.army.mil/el/dots/doer/pdf/doer-1.pdf.

## Master Comment 9.24

Several comments were received that suggested the draft Model LTMP contains insufficient detail, appears to contain a large amount of unnecessary and wasteful sampling and analysis, and is far too general to document achievement of the RAOs.

## *Response*

The draft Model LTMP produced for the FS was not intended to be the working document for the implementation of monitoring. The Long-term Monitoring Work Plan, Sampling and Analysis Plan, and Quality Assurance Project Plan have been drafted and are undergoing final evaluation by WDNR, EPA, and the trustees. These documents, which are based upon the draft Model LTMP in the FS address the commenters' specific issues with the draft plan and contains the level of clarity and detail requested by the commenters.

# White Paper No. 1 – Time Trends Analysis

***Response to a Review of***

## Time Trends in PCB Concentrations in Sediment and Fish:
## Lower Fox River, Wisconsin

March 30, 2001

***and***

***Review of a Document by BBL***

## PCB Trends in Fish from the
## Lower Fox River and Green Bay, Wisconsin

January 2002


***This Document has been Prepared by***

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The Mountain-Whisper-Light Statistical Consulting


**December 2002**

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# ABSTRACT


Commenters took issue with the comprehensive time trends analysis (Time Trends Report [Mountain-Whisper-Light, 2001]) conducted for the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a). They argue that there are declines in PCB concentrations in fish tissue, sediments, and water that are not used or improperly applied in the RI, the *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001). Specifically, they contend that PCB concentrations in fish tissue are continuing to show decline within the Lower Fox River. They dispute the statistical trends analysis conducted for the RI that showed a leveling off of fish tissue concentrations (the "breakpoint analysis") stating that there is no apparent reason for the breakpoint. They also state that the RI used an inappropriate statistical model, did not make the best use of the available data, and that a simple mathematical representation of the data shows a long-term, consistent downward trend. The commenters' analysis is based on two papers submitted in rebuttal to the Time Trends Report: the BB&L Report on *PCB Trends in Fish from the Lower Fox River and Green Bay, Wisconsin* (the "BBL Report") and *Time Trends in PCB Concentrations in Sediment and Fish: Lower Fox River, Wisconsin* by Dr. Paul Switzer. This White Paper presents a response to these comments, in a response/comment format, including defenses of the methodology used in the Time Trends Report, its data handling, statistics, and various approaches.

The Time Trends Report, prepared by a collaboration of three eminent biostatisticians: Dr. Nayak Polissar (Ph.D. from Princeton University), Dr. Kevin Cain (Ph.D. from Harvard University), and Dr. Thomas Lumley (Ph.D. from University of Washington), found that PCB concentrations in fish tissue showed a slow decline with a "breakpoint" in the 1970s followed by a flat decline. This finding is the central dispute raised by the commenters. The position of Dr. Switzer and BBL is that the data show a steady state and continuing decline. The Time Trends Report position is based upon their identification of a physical reason for the breakpoint. The changes in fish tissue concentrations are observed to occur at that period of time when the mass of PCBs released by direct discharge by the paper mills falls below the steady-state releases of PCBs from sediments. Direct PCB discharges dropped significantly in 1971, with continuing discharges through 1997. The fish tissue concentrations reflect exposure to sediment releases, and are subject to decline only at the rates at which sediment PCB concentrations decline. Equally important in evaluating the breakpoint is the biology of the fish themselves; fish exposed in the late 1970s will continue to be present in later years. The Time Trends Report acknowledges that the breakpoints are "best fit" models, and are not precise estimates of the year in which change occurs.

# A INTRODUCTION AND SUMMARY

***Background***

This document was prepared as a response to a review by Professor Paul Switzer of the *Time Trends in PCB Concentrations in Sediment and Fish: Lower Fox River, Wisconsin* (Time Trends Report) (Mountain-Whisper-Light, 2001), which was included in the Draft RI issued in October 2001 as Appendix B. Any mention of a "Time Trends Report" in this response document refers to time trends study by Mountain-Whisper-Light (2001), unless the text notes otherwise or unless it is clear from the context. Professor Switzer usually refers to the Time Trends Report or a section of the Time Trends Report as, for example, "MWL" or "MWL 2.2."

A revised version of the Time Trends Report has been released as an appendix to the final Remedial Investigation Report.

This response document also presents a review of a report prepared by Blasland, Bouck, and Lee, Inc. (BBL), *PCB Trends in Fish from the Lower Fox River and Green Bay, Wisconsin* (BBL, 2002). That report was included as part of a package submitted by the Fox River Group (FRG) during the public comment period.

We have invited our colleagues from RETEC to contribute comments on specific topics that fall outside of our expertise. When they occur, these supplemental comments are prefaced by a "RETEC Comment" annotation.

***Contents of this Document***

This response to Professor Switzer's comments addresses his discussion of The Mountain-Whisper-Light's analysis of time trends in sediments. This response opens with general remarks on his main points and continues with a point-by-point response to each of his written comments. The document continues with a similarly structured two-part section addressing Dr. Switzer's review of The Mountain-Whisper-Light's analysis of fish time trends.

Finally, the document presents a review of BBL's analysis of fish time trends, again a two-part section of general comments and then specific comments keyed to specified sections of the BBL report.

***Sediment Analysis***

Dr. Switzer's review of The Mountain-Whisper-Light estimates of sediment time trends raises several issues, but two stand out. He objects to our analysis that separates the data into many spatial units (with a number of units dropped due to inadequate sample size or time span), and suggests instead a more global analysis combining, at least to some extent, depth strata, deposits, and reaches to gain more precision in the time trend estimates and include more of the omitted data. Second, he does not accept the use of a particular method, "WSEV," for estimating the uncertainty (standard error) of the time trends in sediment PCB concentrations. The WSEV method was used to accommodate the spatial correlation of the data. Dr. Switzer suggests a more traditional geostatistical analysis to incorporate the correlation.

In response, we shall note that, at the outset of our analysis we considered and rejected Dr. Switzer's proposed global analysis of the sediment for two reasons. First, the deposits are quite varied in their shape and spatial profile of PCB concentrations. Developing a global model with common spatial coordinates would be an extensive project with high likelihood that the additional precision would be gained at the expense of bias in estimation of time trends for the spatial units of interest. That is, the apparently more precise trend estimates may not apply to the spatial units for which they were estimated. Also, it would likely be necessary to replace the multiplicity of spatial units with a highly complex global model with a multiplicity of parameters to allow tailoring the model to fit the local time trends, but with actually very little power to detect and fit the local trends. Our use of the smaller spatial units (which are still spatially extensive, typically a kilometer or more in horizontal extent) ensured that the fitted trends were more unbiased for the spatial units considered, at the price of some increase in uncertainty in the trends. Had a very substantial increase in resources and additional time been available, the global route could have been investigated and any gains (such as decisions about just how much to split the spatial units) could have been incorporated in the current approach. Again, the gain from the global approach is uncertain and is likely to be small, due, as mentioned, to the unique spatial profile and, possibly, time trends of the various deposits.

Second, the time trend estimates are to be used by decision-makers who will be considering, separately, the different reaches and also the different depth strata. Decisions are to be made reach by reach, and surface sediment is likely to be considered in a different manner than deeper sediment due to the importance of surface sediments as the matrix at the base of the food chain. Thus, some attention to trends by reach and by depth is necessary. The River shows not just one or two trends, but a multiplicity that are of interest, a phenomenon which we addressed.

Dr. Switzer's proposed approach and our approach present a tradeoff between reducing variance and increasing bias by lumping, versus reducing bias and increasing variance by splitting. We chose the latter route, due to the need for unbiased information at the reach and sub-reach levels.

The second main objection to our approach, our use of the WSEV method for estimating standard errors in trends, reflects, we feel, only a communication problem. Our Time Trends Report's discussion of this method was brief because we wanted to keep technical detail to a minimum. The standard geostatistical model proposed by Dr. Switzer cannot be used with these data due to the large fraction of data below detection limit. This "censoring" is not accommodated by the standard geostatistical model. Also, methods of imputation (such as half the detection limit) would have replaced a large fraction of the data with imputed values.

The WSEV method incorporates the data below detection limit. Further, the method has appeared in peer-reviewed articles in the premier statistical journals of the United States

(*Journal of the American Statistical Association*) and of the United Kingdom (*Journal of the Royal Statistical Society*). We have provided a fuller description of the method in this document.

Finally, the reader may wish to review Section 6.3.2 of our Time Trends Report, which addresses some of the difficulties, and resulting uncertainties, attending a study of time trends of PCB concentration in sediment.

***Fish Analysis***

Dr. Switzer also raised several questions about our analysis of time trends of PCB concentrations in fish and two main points stand out. The first point is, again, lumping versus splitting—combining species and reaches in the estimation process, versus estimating trends separately for each combination from data limited to that combination. Lumping into a more global model would, Dr. Switzer proposes, gain back the substantial fraction of the data dropped for species with data sets with small sample sizes or with an inadequate time span of observations. The larger sample size per analysis would reduce the variance of the estimated time trends. We considered and rejected this approach for two reasons. First, the decisions to be made about the remediation process will be based on trends for individual species within their reaches. Even though the global model would provide such estimates, it is questionable whether they would be unbiased, given the diverse life-cycle patterns across species within a reach, and the different environments of the reaches. Fisheries biologists at the Wisconsin Department of Natural Resources (WDNR) discouraged, at the outset, a global analysis combining species and reaches.

Each reach contains different ecosystems with different species. For example, walleye in the last River reach migrate in and out of Green Bay, but are physically prevented from migrating further upriver. The lake-like ecosystem in Little Lake Butte des Morts is fundamentally very different from that observed in the next two reaches. Food chain differences, different species, and different exposure rates to PCBs account for WDNR's recommendation that we do not globally evaluate changes in fish tissue concentrations. Lumping across species was discouraged because of the obvious differences in exposure pathway dependant upon the trophic status of the species. Exposure to the reservoir of PCB residing in the sediment is drastically different for species such as carp, catfish, or suckers that are in constant direct contact with the sediment than they are for pelagic species such as alewife/shad, white bass and walleye that have little or no direct contact with sediments. On the other hand, lumping across River reaches was not considered wise because of the known quantity, spatial, and temporal heterogeneity of original PCB discharges.

Further, most of the data sets for reaches and species are relatively small, and there would be little power to detect differences among these reach/species combinations in the process of developing a global model incorporating time trends, seasonal effect, and the role of lipids, all of which can vary by species and reach. Thus, similar to the sediment analysis, a global model might appear more precise, but at the expense of increased bias. We chose to avoid bias.

The FRG consultant has suggested that a more global approach is appropriate in this instance, but other comments submitted by the FRG have suggested that a more global approach is not appropriate, for example, in assuming a global sediment-to-water ratio for fate and transport modeling.

A second objection by Dr. Switzer to our analysis is our choice of a linear spline model for estimating time trends and changes in time trends. On a plot of log PCB concentration versus time, the spline model would appear as two straight-line trends joined at a breakpoint, with different slopes before and after the breakpoint. These models, as Dr. Switzer pointed out, have some challenging statistical properties, and he proposed an alternative model. We used the breakpoint model and continue to support it, because the model proposed by Dr. Switzer, and most other models commonly used to accommodate changes in the time trend during the observation period, do not accommodate the wide range of plausible changes in time trends that may happen, including a change from a negative to a zero or positive trend, which was observed in these data. Such a positive trend is plausible on a temporary basis. It is important to be able to detect changes in trend (and without constraining the change to yield only a negative time trend), because the detection of change is an important discovery about time trends in the River and affects our confidence in projections of future PCB concentrations. By using the model proposed by Dr. Switzer, the changes in time trends that have occurred over the course of the River would be constrained to be decreases only and would be only gradual changes with a smoothness that may not be realistic. The spline model is quite flexible in allowing a change in slope at any single time during the time series, and a change of any positive or negative magnitude. The choice is whether to fit a model with greater apparent precision and "smoother" properties that may not reflect the volatility of the River, versus a model with less precision but that can detect a wider variety of changes in trends. The results show that changes in trend are part of the River history. Our time trends analysis has established that trends in PCB concentrations may change over time.

Dr. Switzer also disagrees with our contention that one cannot be confident in predicting the future course of PCB concentration in fish species. In response, we present results from two examples showing how predicted future values differ drastically depending on which model is used to fit the existing data series. These results should not be surprising. They confirm the maxim taught in any regression course: that predicting much beyond the range of the data is very risky. Such predictions rely as much on the assumed model as they do on the data.

***BBL Fish Time Trends Report***

This report fits a simple exponential decay model to the fish data and discards pre-1980 data — to avoid, the authors state, a period when PCB input to the River was changing. They carry out various other analyses, but the simple exponential decay model is their central analysis and is used for future projection of PCB concentrations. It is difficult to use the authors' future projections (or our future projections) for making decisions about this River, though their fitting of models to the data for the period of observation (1980–1999) agrees broadly with our estimated trends during that period, with some exceptions. We note that: (1) the limitation of the data to the post-1980 period has limited the ability to detect changes in trend, (2) adequately fitting a model to a range of observations does not ensure that the model is correct and that extrapolation outside the range is correct (this applies to our study as well), and (3) alternative models that also adequately fit the data over the range of observation have drastically different projected future PCB concentrations. In short, the future is more uncertain than presented in the BBL report.

The BBL report provides no description of how data below the detection limit were handled, and the seasonal effect (which can affect the trends if ignored) was not included in their modeling. It should also be noted that many of the criticisms Dr. Switzer has of our Time Trends Report apply to the BBL report as well.

# B SWITZER REVIEW

## B.1 SEDIMENT: GENERAL COMMENTS

Professor Switzer has provided a critique of our sediment analysis covering three main areas:

1. Data Splitting: The data were split into many small pieces for analysis, and a combined analysis would be more powerful.

2. The WSEV Method is not appropriate. (This is the method used to estimate the variance of time trend coefficients in our models.)

3. The averaging of PCB concentrations from a single core is inappropriate.

We consider each of these topics (and other points) in turn.

### B.1.1 Data Splitting

The review of objects to splitting the spatial data into small units and suggests a more global analysis and use of a different coordinate system. However, given the spatial distribution of the PCB deposits and the individualistic shape and PCB spatial profile, a global analysis is an uncertain venture at best. Given the extent of spatial variation, our spatial compartment analysis was a reasonable approach to the data. There is a tradeoff between a global model and the multiple local models (for local spatial units), and it is a tradeoff of variance versus bias. It is likely that combining horizontal units (deposits) and vertical units (depth strata) would give <u>apparently</u> more precise estimates of time trends, as indicated by smaller standard errors of the time trend slopes. Such a global model can be used to provide estimates for the various deposits and their depth strata in each reach, but there would be no way to check the validity of estimates derived this way for the many spatial units. Thus, for example, a spatial depth stratum sampled at only one time point but covering several geographically dispersed units could help to define a more precise <u>spatial</u> model. However, it would provide no information on time trends, and a time trend estimate for such a spatial unit would be unverifiable. Further, even time trends estimated from a global model for any spatial unit may not well represent that unit, and there would be little power to detect an erroneous representation.

The River is not a spatially smooth phenomenon. Maps of the River indicate fairly discrete deposits with unusual shapes, and individualistic PCB spatial concentration profiles. Thus, there is concern about combining different deposits into the same spatial model. In addition, isopleths of concentration by depth are quite irregular in shape, again leading to our concern that a meaningful global model (for example, a model of an entire deposit or reach) would be very difficult to achieve.

If the time trends are to be more globally modeled, then the modeling would need to introduce interaction many terms between time and spatial location. This would require building a complex model to accommodate the local variation in time trends, both horizontally and vertically, including polynomial terms for spatial variation in PCB concentration and the interaction with time. We recognized at the outset that the River was not "nice and smooth," in spatial variation. The alternatives were: (a) to carry out an extensive exercise in modeling with an uncertain outcome, or (b) to accommodate the spatial variation by working with smaller spatial units. We opted for the latter, which allowed us to achieve the goal of providing time trend estimates for spatial units within a reasonable expenditure of resources. While the global approach may sound attractive initially, there is no assurance that it would provide better estimates.

## B.1.2 Estimation for the Sediment Trends: Marginal Maximum Likelihood and WSEV

### *B.1.2a Less Technical Explanation*

The "WSEV" method was used to provide estimates of uncertainty (standard errors) in our time trends. Estimating time trends in PCB concentration in the sediment cores is complicated by the spatial correlation (similarity of PCB concentrations across small areas) and because a substantial fraction of the measurements are below the limit of detection. Standard geostatistical methods address the spatial correlation but do not explicitly handle the detection limit problem.

A common approach to correlated data in other statistical fields is to explicitly model the average trend but not the correlation. This approach makes estimation easier and more reliable, but less efficient than if the correlation could be correctly modeled. This approach is called quasi-likelihood or marginal maximum likelihood. In the specific case of this analysis, it corresponds to computing trends for the mean of the logarithm of PCB concentrations. The advantage of marginal maximum likelihood, used in our sediment analysis, is that measurements below the limit of detection can easily be incorporated using methods for so-called "left-censored" data (i.e., BDL – "below detection limit") that are encountered in biological and engineering statistics.

The precision of these time trend estimates does depend on the spatial correlation of PCB concentrations, and this precision can itself be estimated from the variability between subsets of the data that are independent or approximately independent. In the current situation of data measured over space and time, we can find these subsets by dividing each spatial unit into "windows" that are sufficiently widely separated to be approximately independent. This method is the "Window Subsampling Empirical Variance" or WSEV (Heagerty and Lumley, 2000). The discussion below gives additional technical details.

In theory, some extra precision could be obtained by explicitly modeling the correlation between measurements, as in a standard form of geostatistical analysis (Cressie, 1993). This standard geostatistical approach would be preferred when no measurements or very few of them are below the limit of detection. The only computationally straightforward way to handle measurements below the limit of detection in the standard geostatistical model is to replace them by some arbitrary small value, an approach that is undesirable when such a large fraction of the data would have to be replaced. Another option is to try replacing the censored data by values imputed from a statistical model. After replacement of the BDL data, a standard geostatistical analysis could be performed incorporating spatial correlation. A sensitivity analysis would be necessary to see the extent to which the estimated time trends and their standard errors, and thus the conclusions of the analysis, depended on the method of replacing the BDL data. Without actually doing these analyses it is not possible to determine whether the potential bias and sensitivity to the choice of imputation method would offset the extra precision that is theoretically expected from a geostatistical analysis.

### B.1.2b WSEV Technical Narrative

The use of marginal maximum likelihood together with Weighted Subsampling Empirical Variance (WSEV) to estimate standard errors (Heagerty and Lumley, 2000; Lumley and Heagerty, 1999) is a generalization of the GEE method (Zeger and Liang, 1986) that is widely used to estimate parameters in models for repeated measurements on individuals. If the expected value of the log likelihood for each individual spatial location has its maximum at a particular (common) set of parameter values, then the expected value of the sum of all these log likelihoods also has a maximum at the same common value, regardless of the form of correlation between these values. This means that the temporal and spatial trends in PCB concentration can be estimated using the same software that would be used if the measurements were independent. There is a substantial benefit of this equality of parameter estimates between two data sets of identical observations, where one data set has correlated data and the other does not. The benefit is the widely available and well-understood methods and software for analyzing data that cannot be observed beyond a certain value (censored data), such as the PCB concentrations below the limit of detection. These methods can be applied to the correlated data to produce parameter estimates, such as the coefficient of time in a time trends model, without having to consider the correlation.

Although the estimates resulting from marginal maximum likelihood are unbiased (or more precisely, are consistent), their precision when applied to correlated data differs from what would be obtained with independent data. Correct standard errors, which may be larger or smaller than those under independence, can be obtained from the WSEV method. Heagerty and Lumley (2000) gave precise conditions for the WSEV estimator to be consistent; heuristically, the important condition is that the correlation falls off sufficiently fast with distance that the data can be divided into approximately independent subsets that are used as approximate replicates for computing a variance. Lumley and Heagerty (JRSSB, 1999) discuss the relationship of WSEV to a number of well-known methods from statistics and econometrics, including variants of the bootstrap.

### B.1.2c Technical Details of WSEV

WSEV can be viewed as an extension of either the window resampling bootstrap for spatial data (Politis and Romano, 1994; Sherman, 1996) or of the information sandwich estimator for longitudinal data (Liang and Zeger, 1986) and time series (Newey and West, 1987). The variance of the parameter estimates from estimating functions like those for marginal maximum likelihood is of the form $I^{-1}JI^{-1}$ where $I$ is the expected value of the derivative of the estimating function and $J$ is the variance of the estimating function. As the estimating function in this case is a mean of contributions from each location, we can use the observed value of the derivative to estimate $I$ under very weak assumptions. The variance matrix $J$ cannot be estimated by a similar plug-in sum of squares and products, so other techniques are needed. Lumley and Heagerty (1999) show that a fairly general approach is to use a weighted sum of squares and products. If the contribution to the estimating function from the $i^{th}$ observation is $U_i(\beta)$ so that $\hat{\beta}$ solves:

$$\sum_i U_i(\beta)=0$$

then we use:

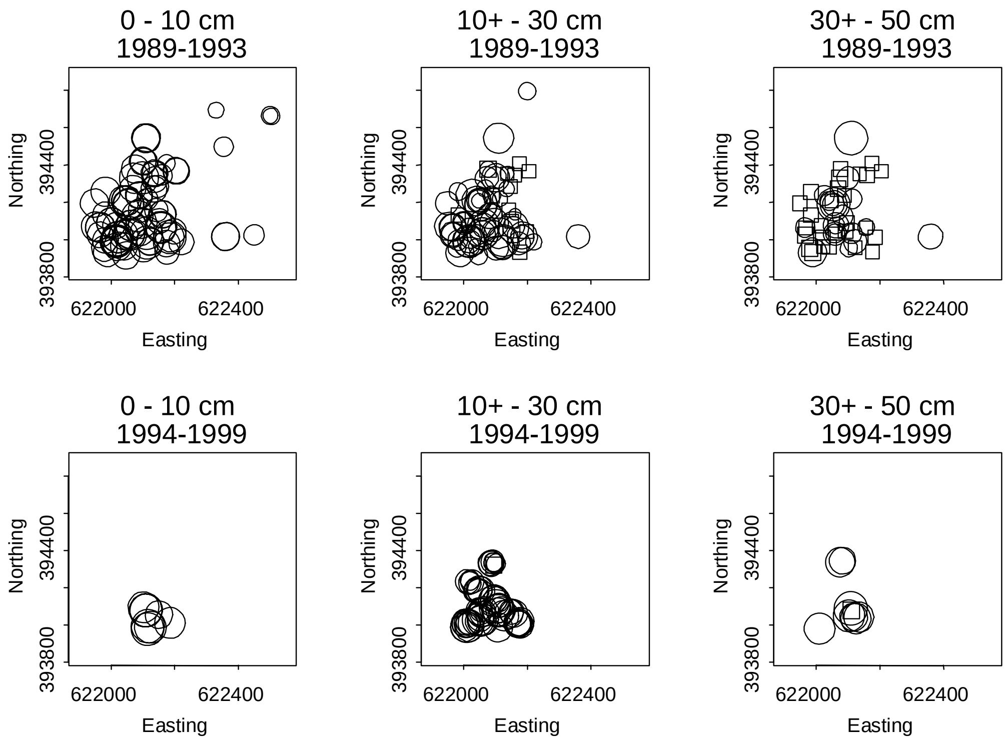
$$\hat{J}=\frac{1}{n}\sum_{i,j} w_{ij}U_i(\hat{\beta})U_j(\hat{\beta})^T$$

where $w_{ij}$ is close to 1 for pairs $i$ and $j$ that are close together and close to 0 if $i$ and $j$ are far apart. Heagerty and Lumley (2000) show that one choice of $w_{ij}$ gives WSEV a computationally straightforward method that is equivalent to estimating $J$ by the window resampling bootstrap. The consistency of the estimator $\hat{J}$ is proved under conditions on the fourth moments of $U(\beta)$ and the strong mixing coefficients of the random field that is being measured, by using a minor adaptation of proofs for the window resampling bootstrap by Sherman (1996).

### B.1.3 Sampling Bias

It can be seen from Figure A-2 of our Time Trends Report that the sampling scheme used to take sediment measurements was not random, as can be seen, for example, in this figure. The samples taken in the later period, 1994 through 1999, are more localized in the south and west area (which has higher concentrations) than samples taken in the earlier period, 1989 through 1993. In general, an area with high levels at an earlier period would be more likely to be resampled at a later period. Unless corrected, this sampling bias will tend to give a false impression that PCB concentrations increase over time or else decrease at a lower than actual rate. Suppose, for example, that a given area has 10 points sampled from a sub-region with PCB concentrations of about 500 and 10 points from the remainder of the area with concentrations around 250. At the second sampling, 20 measurements taken from the highly contaminated sub-region show concentrations averaging about 450. Comparing the overall averages of 375 at Time 1 and 450 at Time 2 suggests that PCB concentration has increased, but in fact, the concentration has decreased in the only area being resampled.

## FIGURE 1 SAMPLE LOCATIONS BY NORTHING AND EASTING COORDINATES DURING 1989–1993 AND 1994–1999, DEPTH STRATA OF LITTLE LAKE BUTTE DES MORTS DEPOSIT GROUP AB (0 TO 50 CM)




**Notes:**

[1] Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

[2] This figure was originally included in the Time Trends Report in Appendix A as Figure A-2.

Our approach to correcting this bias is to build a relatively detailed spatial model of the PCB concentrations by dividing the River into regions and then modeling the spatial trends over each region. The sampling bias occurs because those taking the samples tend toward "hot spots" over time, within a spatial profile of contamination that is roughly constant over time. This background contamination can be estimated and subtracted out (or controlled) so that we consider only the changes over time from this spatial profile.

There are at least two other approaches to controlling bias from sampling patterns: (1) a method that directly corrects for the bias, designated here as "direct bias correction," and (2) a reweighting method. For the bias correction method, suppose that the regions sampled in the first wave are divided into those small regions that are subsequently resampled and those that are not. If the small regions that are resampled have twice the PCB concentration on average compared to those not resampled, we can divide subsequent measurements by two to make them comparable with points that are not resampled. In the example above, if we divided by two all the measurements from the highly contaminated sub-region, we would find the average decreasing from 250 at Time

1 to 225 at Time 2. More sophisticated versions of this approach are possible but require progressively more complicated statistical analysis and programming.

The reweighting approach is commonly used in surveys of human populations. If a particular highly polluted sub-region receives twice as many samples as a less polluted sub-region, we can correct for this difference by giving each sample half as much statistical weight in the analysis. The reweighting approach is most reliable when the sampling has been done according to a prespecified plan, and is less reliable when this sampling plan must be estimated retrospectively from the data. In our illustrative example above, this approach would correspond to an analysis that used only the points from the highly contaminated sub-region, which would correctly indicate a decrease in contamination.

Neither of these two additional methods was used due to the need, in using them, to model the sampling "plan" used in the retrospective data. This would also be an additional spatial analysis and an undertaking well beyond the scope and resources of this project.

### B.1.4 Core Averaging

The reviewer objected to the averaging of PCB concentrations within a stratum from a single core sample. Averaging measurements from a single core sample within a specified depth stratum is a relatively unusual practice in a standard analysis of space-time trends. The separate samples from a single core provide an estimate of the so-called "nugget effect" that is important in modeling the correlation of measurements over space. (The term "nugget" refers to geological applications, where it might be a physical nugget of the contaminant at a particular location, such as a discrete unit of PCB. It could also be a small volume with an unusual concentration.) Given the large number of measurements below the limit of detection, we are using a method that does not require modeling the correlation of measurements over space; thus, we do not need to estimate the nugget effect. In fact, having multiple separate samples from the same core is disadvantageous for our approach, as cores with more measurements would receive more weight in the analysis. With the WSEV method, we can obtain a better estimate of average PCB trends over time by core-averaging so that each core, which represents a single sampling location, receives the same weight in the analysis.

### B.1.5 Coordinate System

Dr. Switzer proposed a different coordinate system based on the River midline as one coordinate and a second coordinate perpendicular to it, with, presumably, depth measured in the usual manner. This approach does not seem at all promising. The maps (Figure 5-8) on page 220 of our Time Trends Report show that the River and its deposits are not very symmetrical. For example, Little Lake Butte des Morts has nonsymmetrical deposits that are not symmetrically placed along the River. The south end of Little Lake Butte des Morts (closest to Lake Winnebago) has a deposit on the west side of the River but not on the east, and deposits AB, C, and group POG are each found on just one side of the River. A complex spatial model would be needed to accommodate this asymmetry. A similar complexity can be found in the De Pere Reach, as shown in Figure 8 of our Time Trends Report. In the more southern part of this reach, the deposits tend to occur on both sides, while farther downstream (north) deposits tend to occur on one side of the River. A river-center coordinate system would require complex polynomials to describe the spatial variation in concentrations. Thus, the proposal for River center coordinates and the more global modeling of PCB concentrations would be merely the starting point for extensive explorations that we believe would result in a model of daunting complexity. By avoiding highly complex models, the data splitting used in the Time Trends Report was a practical way to obtain trend estimates within a reasonable time and with a reasonable use of resources.

The reviewer suggested a system of 10 parameters to model spatial effects (constant term and all linear and second-order quadratic terms—including cross terms). We were concerned about over-fitting the data and opted for a simpler system with fewer parameters, including only linear and quadratic terms based on the fixed coordinates available with the data ("northing and easting," which are equivalent to Y- and X-plane coordinates), as well as depth. We limited ourselves to the fewer number of parameters to avoid over-fitting some of the relatively small data sets. In retrospect, it might have been helpful to use horizontal (rectangular) coordinate axes that were oriented more along and perpendicular to the River (by a simple rotation of the northing and easting coordinate system carried out separately, per deposit) and a linear term for depth. In summary, our coordinate system was a consequence of our decision to work with smaller and more tractable spatial units, rather than launch a very labor-intensive (and possibly futile) global modeling exercise.

### B.1.6 Meta-Analysis of Sediment Time Trends

We note that the meta-analysis of time trends is a way to produce a combined estimate of time trends without fitting a global modeling. This is a more accurate estimate of the "average" time trends occurring during the era of the sample collection. It is a useful summary figure because it represents the percent rate of removal of PCB mass from the surface sediment of the deposits incorporated in the meta-analysis. The meta-analysis is a way to combine the slopes, meaningfully, and allows a substantial gain in summarizing the data. We note that the reviewer does not object to the meta-analysis but considers it weaker than the (unproven) results that <u>might</u> be obtained by a more global modeling.

## B.2 Response to Specific Points Made in the Review

### B.2.1 Methods for Sediment Analysis

***Comment:***

In MWL 2.1, data were allocated to five depth strata and separate spatial models were developed for each of the depth strata. If a time trend analysis for sediments at depth were considered meaningful, it would have been better to model spatial PCB variation using a more parsimonious, less arbitrary, single three-dimensional spatial model—without an artificial partition of the data into strata. For example, a quadratic spatial PCB model with three spatial coordinates would have 10 parameters. This should be compared with the confusing array of 35 unrelated parameters needed for the separate two-coordinate quadratic models with linear depth modeling within strata. A three-dimensional model allows for PCB gradients that are not otherwise possible. The dependence of the linear time trend on depth could then be modeled by a trend parameter that is itself an explicit function of depth.

***Response:***

We commented in Section B.1.1 on the hazards of the global modeling approach. Here, more specifically, it seems overconfident to assume that the 10 spatial parameters proposed in the review would cover the PCB variation across the varying configurations encountered in the several reaches. Also, the strata are not as arbitrary as implied. The various parties concerned with the River have carried out extensive research and reporting using these strata. Given the need to work with units smaller than reaches or full deposits, it was valuable to use the spatial units familiar to this community. The reviewer's reference to "35 unrelated parameters" is not clear. True, our approach collectively used a large number of parameters in the total collection of all models, because the River is extensive and has a number of different deposits. In working with a complex phenomenon, we cannot necessarily get by with a simple answer. The review notes that, "a three-dimensional model allows for PCB gradients that are not otherwise possible." Does the reviewer mean that the more global model can be used to extrapolate time trends to sediment parcels that have only sparse measurements? We question the validity of extrapolation from a parsimonious but poorly fitting global model. If the reviewer means that a more global model with a larger set of parameters than was used in our model can provide gradients with respect to each of those spatial parameters, then we agree. However, the gradients are likely to be meaningless, if the global model does not fit well, which is likely.

***Comment:***

Multiple measurements from a single core within the same stratum were averaged and represented by a single depth and single PCB value. From the information provided in MWL, it seems that 40% of the original data were replaced by core averages. Core averaging was introduced to deal with spatial correlation between observations within the same core. Short-range spatial correlations are better handled explicitly with a geostatistical model. Core averaging has some problems:

1. Depth information is lost to the analysis.

2. Short-scale PCB gradient information is lost to the analysis.

3. Averaged values will have different variance characteristics than single values.

4. The core average of log-transformed PCB concentrations is a biased estimator of the logarithm of the core-averaged PCB concentrations, so in this sense they are not compatible with remaining data that are not derived from core averages.

***Response:***

The short-distance PCB gradient information is difficult to exploit in the presence of censoring (below level-of-detection data), and we used a method that does not require it.

The issue of the variance characteristics of core-averaged values also would be most important for a different analysis than the one used, as discussed in the body of our response (in Sections B.1.2a and B.1.4). Experience in marginal modeling of correlated data reveals that giving equal weight to "clusters" of highly correlated observations is better than giving equal weight to the observations themselves. On point (4), Professor Switzer is perhaps correct that it would have been better to average the values after log transformation rather than before.

***Comment:***

MWL 2.1 claims that core averaging does not affect statistical significance because of cancellation of the effects of reduced sample size and increased power. This is conjecture, and it is not clear that power is increased in any event.

***Response:***

Increased power is not the motivation for core averaging; the motivation is to achieve equal weight for equal information as described in the response to Comment 1. We believe that power is not lost, but core averaging is important whether or not there is a loss of power.

***Comment:***

The discussion of lognormal distributions in MWL 2.1 seems a little confused. For purposes of the statistical analysis, the requirement is that the regression residuals be lognormally distributed. It matters not that the combined data look like they have a single lognormal distribution because the data do not have a common mean value according to the regression model.

***Response:***

Professor Switzer is entirely correct that the explanation was unclear. The model-checking for the analysis presented in the Time Trends Report should be (and was) performed on residuals.

### B.2.1a Maximum Likelihood Method

***Comment:***

The maximum likelihood method in MWL 2.2 is used to obtain estimates of the model parameters that make the data most likely. The estimates are tied to the assumed model structure and the assumption that the model residuals ("noise") are independent random variables that have the same lognormal distribution at every time and location. The discussion in the report about the lognormal distribution requirement seems to miss the point.

***Response:***

This issue is again a fault in the previous explanation of the analysis, rather than the analysis itself. The method we used was "marginal maximum likelihood" or "composite likelihood." It is computationally similar to maximum likelihood and has similar statistical characteristics including high precision as long as the correlation between observations is not too strong. An earlier section contains a more detailed discussion of the methods, including some technical information. See Section B.1.2.

***Comment:***

The maximum likelihood approach is indeed flexible enough to accommodate other models, as is claimed in the report. In particular, it could have been used to fit an overall three-dimensional model with spatially autocorrelated residuals.

***Response:***

If there had been no or few measurements below the limit of detection, this approach would clearly have been preferable and would be standard. However, the routine methods for fitting spatially autocorrelated models do not allow for "censored" (below detection limit) measurements. With small numbers of such measurements, various ad hoc approaches are known to work well, but given the large fraction of censored measurements in this study we did not feel that "making up" nearly half the data was appropriate. The arguments for the superiority of the spatial autocorrelation approach are not compelling with this level of incompleteness.

This issue is further discussed earlier in this document. See Section B.1.2.

***Comment:***

The discussion pertaining to testing statistical significance of the hypothesis of a zero time trend omits an important point – to reject this null hypothesis is merely a question of getting enough data. The real goal should be to obtain the plausible range of time trend rates that are consistent with the available data. Testing the hypothesis of no PCB change is generally superfluous.

***Response:***

We note that we have supplied what the review refers to as "the real goal," that is, "a plausible range of time trend rates that are consistent with the available data." We supplied 95 percent confidence intervals for rates in our results. We would like to comment on the review's consideration of "statistical significance." In a study involving huge numbers of subjects, very minor and unimportant differences can be statistically significant by chance alone. Thus, in a large study, noting that a result is statistically significant may not be a particularly meaningful comment. Similarly, in a small study, a common mistake is to assume that a trend that is not statistically significant indicates a zero trend. We have not made that mistake in this Time Trends Report. Our analysis involved quite variable data, small sample sizes, and phenomena for which a finding of statistical significance is not common. The scientific community <u>is</u> justifiably interested in statistically significant results as indicating a finding that is not consistent with random variation. We discussed this issue in the Time Trends Report, cautioned against over-interpretation of non-significance, and explained the concept of statistical significance. We believe that the readers are entitled to see the statistically significant results, which are certainly not a detraction but are an added feature, and we have included confidence intervals as well.

### *B.2.1b Spatial Dependence*

***Comment:***

MWL 2.3 contains the beginnings of a geostatistical analysis, as seen in the variogram plots used to describe spatial autocorrelation of PCB values. However, nothing is done with the geostatistical analysis.

***Response:***

We did not use the geostatistical analysis due to the large amount of below-detection data. See our discussion of why we chose the marginal model rather than a spatially autocorrelated model (Section B.1.2). The variograms presented in the Time Trends Report are intended to demonstrate the presence of spatial dependence. They were not used in a formal way in the analysis.

***Comment:***

There are, nevertheless, a few problems here:

a. The use of core-averaged data negates the possibility of estimating the variogram at the short distances that are critical to estimation of the measurement error or nugget effect.

b. The fitted smooth curves on the variogram plots probably do not represent valid variogram models that must obey certain mathematical constraints.

c. The variogram analysis seems to ignore the spatial nonstationarity of the mean, i.e., differences between data values are not adjusted for differences in their mean values.

d. A better approach would have been to fit parameters of a valid variogram function using the maximum likelihood method in the context of a nonstationary mean function that also depends on location.

***Response:***

These comments describe an alternative analysis that would definitely have been appropriate with little or no data below the limit of detection. We do not agree that this approach would have been better with the current data.

### *B.2.1c Addressing Spatial Dependence Using the WSEV Method*

***Comment:***

This unconventional method in MWL 2.4 is used to derive measures of trend uncertainty when there is spatial autocorrelation in the data. The essence of the method is to choose a geographic grid partition for averaging within grid cells – the idea being that there will be little autocorrelation between quantities computed on a coarse grid scale, enabling standard methods to be then used for standard error estimation. The coarseness of the grid partition is determined by an algorithm that I did not understand.

I don't know if this method has a firm theoretical underpinning or whether it relies on the heuristic argument given above.

***Response:***

The method does have a firm theoretical underpinning. A brief technical discussion was offered earlier (Section B.1.2), but for the full details of strong mixing random fields, interested readers will need to consult the *Journal of the American Statistical Association* paper that is referenced (Heagerty and Lumley, 2000).

***Comment:***

The WSEV method was proposed to address the issue of spatial correlation's effect on standard error estimates of time tend parameters. However, if the geostatistical modeling of the preceding section had been carried forward, fully and correctly, then there would be no need to use the ad hoc WSEV method.

***Response:***

Again, we used the WSEV method precisely because we do not regard a simple geostatistical model as necessarily reliable with this much data below the limit of detection (without extensive sensitivity analysis). The description of WSEV as "ad hoc" is excessive, although perhaps due to insufficient explanation in the original Time Trends Report. Please see our expanded explanation in this response, in Section B.1.2.

### *B.2.1d Geographic Grouping of Data*

***Comment:***

The geographic grouping of MWL 2.5 should have been called geographic splitting of the data. Data splitting is generally an inefficient approach to dealing with spatial heterogeneity. The downside of a separate analysis for each of the resulting deposit groups is a plethora of time trend estimates, each with reduced statistical precision. The reduced precision is a serious problem, and one should try to create as few deposit groups as could be justified by a heterogeneity analysis. Spatial clustering of observations is not, by itself, a reason to do data splitting with a separate time trend analysis for each cluster.

***Response:***

In our earlier comments (Section B.1.1) we considered the issue of splitting and the tradeoff between reduced variance and increased bias. An expedition heading toward a global model cannot be justified if time and resources are sufficient for only one serious expedition. We invite other scientists to carry out this more global modeling and to present and compare their results with our findings. Our spatial units are still quite large horizontally, commonly one or more kilometers in extent. Further, we tried to enlarge the spatial units enough to include an adequate sample size.

***Comment:***

A much better approach would be to model PCB concentrations and the concentration time trend as flexible functions of distance along the reach. These functions could be multiparameter splines, for example. In the next section, I describe appropriate spatial modeling for River reaches.

***Response:***

Please see our Section B.1.5 of this review. There we describe the difficulty of using distance along the reach.

### *B.2.1e Models for Variation in PCB Concentration in Space and Time*

***Comment:***

In MWL 2.6, the time trend is modeled as an annual rate of PCB change, with adjustments for spatial variability and depth (separate spatial adjustments within each deposit group and depth interval, and separate depth adjustments within each deposit group). The idea of spatial adjustment of time trends is important but the execution raises questions. Earlier, I commented on the complexity, introduced through the creation of depth intervals and deposit groups, that can sharply reduce the precision of time trend estimates and cloud their interpretability. I also suggested more parsimonious ways to address issues of spatial heterogeneity.

***Response:***

We addressed this issue in our summary comments (Section B.1.1). There is complexity (perhaps "multiplicity" is a better word) to many spatial units defined by depth and deposit groups. There will also be complexity in a global model that truly reflects local spatial concentrations. Further, the global model would be used to infer concentrations to local spatial units (for the most part this is untestable). The remediation of the River must address discrete spatial units and not the River as a whole or even a reach as a whole.

***Comment:***

The particular model of Equation 2 in MWL 2.6 is curious in its method for describing spatial location through northing and easting coordinates. Furthermore, the model has no cross-product term that makes it not-invariant to coordinate rotation.

***Response:***

We used a northing and easting coordinate system (similar to "X and Y coordinates") to indicate locations of samples. We earlier (Section B.1.5) indicated the reason for not including cross-product terms in the model. However, in retrospect, we feel that rotating (per deposit) our rectangular coordinate system to be more in line with the River might have been helpful for some of the deposits.

***Comment:***

A more natural description would start with a centerline along the River reach. A sample location would then be described through its orthogonal [nearest] projection onto this centerline. The position on the centerline becomes one coordinate of the sample location, and the signed distance to the centerline becomes the second coordinate. With this coordinate system the spatial model coefficients are more readily interpretable and further simplification is possible.

***Response:***

This has been covered elsewhere, such as in Section B.1.5.

***Comment:***

Finally, a single flexible spatial model for the River reach seems preferable to separate models for artificially designated subreaches. Scatterplots such as those portrayed in Figures 13–17 would be more interpretable since they would then directly show variation along the River reach and across the River reach.

***Response:***

Again, we noted earlier the need for splitting the data into smaller units. The issue is, again, a potentially unrealistic global model versus a practical local model. See Section B.1.1.

***Comment:***

The modeling of separate linear depth adjustments within each of the selected depth ranges leads to unnecessary complexity and discontinuities in the spatial model.

***Response:***

The spatial model for the depth strata may indeed lead to discontinuity in the estimated spatial concentration as a function of depth, in passing from one stratum to the next. However, the local spatial modeling in each depth stratum would represent the bulk of the sediment in that stratum. There may be discontinuities at the edge, but the sediment as a whole would be reasonably described. Any fitting process will include error in fitting (inherent in all models for any real phenomenon), and the discontinuity would fall into that category. The error at the interface between depth strata must be traded off with the need for a well-fitting model for the bulk of sediments within a spatial unit. We wanted to avoid introducing more parameters to the model to require continuity at the interface of the strata. Again, "the unnecessary complexity" was, in fact, a necessary simplicity in the decision to address spatial complexity by working with smaller spatial units. Once again, it is the issue of an untried and potentially unrealistic global model versus a practical, local model.

***Comment*:**

As suggested earlier, a full three-dimensional spatial model would be more natural if time trends of sediments at depth were thought to be meaningful. The relation of the time trend to depth could be modeled directly using a parametric function where the time trend changes continuously with depth.

***Response:***

This is, again, the global model suggestion. It is a nice idea, but it would require additional parameters to introduce the time and depth interaction. We must emphasize again that data splitting was necessary to avoid extensive exploratory analysis, and that in working with smaller and more manageable units, we had a real and pressing need to minimize the number of parameters in the spatial model.

***Comment:***

The problem of disentangling spatial variation from time trend is thorny, and having a spatial adjustment in the time trend model will not necessarily take care of the problem.

For example, suppose there were data at just two time points (not atypical for sediment groups) but that the early data and later data are taken from different areas. If the early data had high PCB and the later data had low PCB, then the model cannot distinguish easily between a time trend and spatial trend in such a situation, i.e., where sampling time and sampling location are highly correlated. Reducing the potential for high correlations between space and time is another reason not to subdivide the data into sediment groups.

***Response:***

This problem of confounding (or correlation) is real. If spatial trends and time trends are confounded, then the time trend may be underestimated, as may the spatial trend. In fact, if there is a strong correlation of time of sampling and spatial dimensions, it is impossible to accurately determine either the spatial trend or the time trend—a potential liability of smaller units of analysis. However, three-quarters of the correlations between time of sampling and single spatial coordinates of the sample (such as northing or easting of depth) were less than 0.3, so that most time/space correlations were quite weak. (See Section 2.6 of our Time Trends Report.) Again, the alternative global model may avoid the risk of a spurious trend for a small area induced by correlation of sampling date and location, but may also yield a spurious trend for the same small area due to lack of power to appropriately fit the model to the trends of the small area. Further, the small areas are not so small and may have considerable spatial complexity of PCB concentrations. We hesitate to pool these relatively large "small" units further.

### B.2.2 Sediment Results

#### *B.2.2a Number of Observations*

***Comment:***

After the sample size reduction due to core averaging, the number of observations used in the analysis of MWL 4.1 was further reduced by 20% because of insufficient number of observations or time spread for depth-stratum, sediment-group combinations. This unneeded reduction is a product of the unneeded splitting of the data into depth strata and sediment groups, and it further weakens the precision of time trend estimates.

***Response:***

First, the sample size was reduced from 1,980 to 1,618 (an 18 percent reduction) consequent to the data splitting. In general terms, this approximately 20 percent reduction would lead to confidence intervals for rates of change that are approximately one-tenth longer than they would be for a 20 percent larger data set, based on the square-root relationship between sample size and precision. This difference is rather modest. If the global modeling could be made to fit well with many fewer parameters, additional precision might be gained. We have commented on the difficulty of the global approach and the possibly that it would not work at all. Again, it is a question of practical splitting versus a potentially unrealistic global analysis.

***Comment:***

The sampling design issue is not discussed by MWL. The unanswered question concerns the possibility of selectivity of sampling locations, particularly at later collection times.

For example, if later measurements were preferentially located near earlier hot spots, then the subsequent analysis needs to account for such sample location selectivity.

***Response:***

First, it is worth noting that the spatial variability in PCB concentrations is substantially greater than the more subtle variation over time that we have detected and reported. Ten-fold variation across a depth stratum and 100-fold variation across a horizontal extent of a deposit are not uncommon. Thus, in any modeling, the spatial component will dominate. We did report briefly on space/time correlation of sampling in Section 2.6 of our Time Trends Report. In this response, we commented earlier (Section B.1.3) on the difficulty of retrospectively incorporating the sample design into the analysis, but indicated some methods for doing so.

### B.2.2b Geographic Groups for Time Trend Analysis

***Comment*:**

Geographic grouping, as implemented in MWL 4.2, is a wasteful way to use the data and results in too many imprecise unrelated PCB time trend estimates. See my earlier comments on geographic grouping under the heading of Sediment Methods.

***Response:***

This is an incorrect assessment of the geographic grouping. See our comments elsewhere (Section B.1.1 and response to other specific comments in Section B.2).

### B.2.2c Time Trends in Sediment Concentrations

***Comment:***

MWL 4.3 states that "the deposit group and depth combinations that are statistically significant will very likely have true non-zero rates of change over time." Far too much is made of the notion of statistical significance for the implausible null hypothesis of unchanging PCB concentrations. Failure to detect change by a test of significance is simply an indication of insufficient data relative to the size of the change.

***Response:***

Statistical significance is useful in a document addressed to non-statisticians who must make some decisions. These decision-makers will find statistical significance useful if they also interpret non-significance correctly. In Section 6.3.1 of our Time Trends Report we coached the reader on the proper use of the confidence intervals for time trends, and in Section 4.3 of that Time Trends Report we explained statistical significance.

It is not clear why the reviewer, in his comment here, considers unchanging PCB concentrations to be "implausible." By unchanging, of course, we do not mean exactly zero, but practically zero. There could well be time trends that are close to zero. The reviewer is certainly correct that not finding statistical significance does not mean lack of a trend. We have pointed that out in our Time Trends Report. Again, for an audience of non-statisticians, statistical significance, properly interpreted, is a helpful comment in a data set of this size and with the variability inherent in the data.

***Comment:***

Furthermore, the power of the tests is sharply reduced by data splitting. It is for this reason that one sees the erratic variety of 46 different time trend estimates in MWL Table 9 and MWL Figures 20–28, with about one-fourth of these claimed to be significant.

***Response:***

Again, the issue is one of global modeling versus local modeling. The statement, "erratic variety of 46 different time trend estimates," is a qualitative judgment that these varying slopes somehow represent fictitious variation. There is no reason to assume a lack of real variation in time trends.

### *B.2.2d Time Trends by Reach*

***Comment:***

MWL 4.4 first notes that estimates of time trend are typically not precise and vary erratically from one sediment group to another. As explained above, this is an expected consequence of the multiple splits of the data. To overcome the obviously not meaningful results of the multiple estimates of time trend, this section calculates an average time trend for a depth stratum, across all deposit groups in a reach. This ad hoc combination is certainly a step in the right direction, although the precision that was lost through inefficient modeling of the spatial adjustments in each sediment group is not recovered.

***Response:***

We commented earlier on this meta-analysis (Section B.1.6). The reviewer's statement that the results are "obviously not meaningful" is not "obvious" and is not supported by any fuller discussion. It is difficult to respond to an unsupported statement such as this, but we would be interested to hear a fuller explanation.

***Comment:***

MWL Table 10 suggests an annual PCB reduction of 10%–15% in each of three reaches for the topmost depth stratum, and no change in the Appleton Reach. The statistical precision of these recombined time trend estimates is moderate, although with other modeling approaches the precision could be further improved.

***Response:***

The "other modeling approaches" presumably refers to the global modeling approach with the problems that we have referred to (Section B.1.1).

***Comment:***

MWL cautions against using the PCB time trends for reaches for purposes of future PCB projections. The caution stems from the fact that the weights used to combine estimates from different sediment groups might change over time. However, the weights are unlikely to change enough over a decade or two to substantially alter projections.

***Response:***

This comment refers to meta-analysis (Table 10 and associated text). There is no basis supplied to support the statement that "the weights are unlikely to change enough over a decade." A considerable part of the controversy about these time trends is whether they will continue into the future. We are quite confident about what was happening during the period of data collection, but projection into the future is fraught with difficulty. First, the projection has to be supported by an assumption of continuity of either physical processes or just simple statistically calculated rates. What is the assurance that the recent physical processes will in fact continue? The review does not supply any basis for the assumption that the mass of PCBs in different parts of the River will stay the same over a decade.

**RETEC Comment:** Both the Green Bay Mass Balance Study (EPA, 1989) and the FRG's recent submittal with their response to comments (LTI, 2002) support that transport conditions have and will continue to change within the River. In fact, erosional conditions were identified by the FRG's consultant in Operable Unit 4 (OU 4), which they suggested were likely a result of lower water levels in the Great Lakes (LTI, 2002, page 2). Great Lakes levels are expected to in fact recede further, 0.7 to 2.4 feet predicted by 2030, with greater reductions at later times (e.g., 2 to 5 feet) by 2090 on Lake Michigan (EPA, 2000). This will result in yet further erosional conditions on the River.

***Comment:***

In any event, this concern could be addressed by combining PCB projections rather than combining PCB decrease rates.

***Response:***

There is no controversy in this comment. It is true that by assuming a steady state for the processes that have been occurring over the period of data collection and assuming these processes continue, we could then estimate PCB rates of change in the future. The rates of change would be dominated by the more slowly decreasing deposits. This statistical exercise could be carried out based on our findings or on any modeling effort. We do not consider such an effort very useful, given the uncertainty about the future.

## B.3 PCB CONCENTRATION IN FISH

The review by Dr. Switzer makes four main points concerning our analyses of PCB concentration in fish:

1. Our analysis is wasteful of the data.
2. We have used an inappropriate model.
3. Reliable future projection of trends can be made.
4. There is a declining trend in PCB concentrations.

Most of the detailed comments fall under these points.

Our response to the review is divided into three parts:

1. General comments related to model selection.

2. Our response to the reviewer's four main points.

3. A listing of all of the reviewer's detailed comments with our response.

## B.3.1 Some General Comments on Model Selection

We will begin by considering an important issue concerning the philosophy of model selection. The data analysis task can be conceptualized in two very different ways: (1) finding a model that best fits the existing historical data, versus (2) finding a model that is appropriate for estimating PCB concentrations at some future date. Approaches (1) and (2) might be called "fitting" and "projection," respectively.

The "fitting" approach is the one most commonly used for data analysis. The goal is to find the simplest model that is consistent with the data. Unless there is evidence that a more complex model fits better, one accepts the simpler model. In our time trends analysis we used this approach when deciding, for each species/sample type/reach combination, whether to accept the breakpoint model or the simple exponential decay model. (See Sections 3.4 and 3.5 of our Time Trends Report.) We accepted the simple exponential model unless the breakpoint model provided a statistically significant better fit to the data. This philosophy of parsimony is quite reasonable for describing a historical data series. For example, carp whole-body samples from Little Lake Butte des Morts were consistent with a breakpoint (change in slope) in 1987 with a nearly level post-break slope. On the other hand, northern pike fillets (with skin) in the same reach could be represented by a single negative slope without a breakpoint. (See Table 18 from our Time Trends Report.)

In contrast, under the "projection" approach the goal is to predict PCB concentration at some point in the future. For this purpose, the model selected under the "fitting" approach may or may not be the most appropriate. Suppose both a simple model and a more complex model are compatible with the observed data and that both are scientifically plausible. In this situation, it is not obvious which model is better for projecting into the future. The best approach may be to fit both models, plus any other models that are compatible with the data and are scientifically reasonable. Comparing the predictions of these models shows the sensitivity of the projection to the model assumed.

The distinction between these two approaches is important. Under the "fitting" approach, the simplest model that is consistent with the data should be selected as the best model. Under the "projection" approach, multiple models, some complex, will be selected, based on scientific judgment and consistency with the data. Later (in Section B.3.2c), we give some examples fitting different models to the same data, which illustrate how different future projections can be among models that all fit the observed data well.

## B.3.2 Response to Four Main Points of the Review

For each point, italic type indicates a paraphrase of the reviewer's comments, followed by our response.

### *B.3.2a Wasteful Use of Data*

***Comment (Paraphrased):***

The Time Trends Report uses statistical methods that are wasteful of the data. A separate model is fitted to each species, sample type, and reach, and data are not used at all if the sample size is too small for that species, sample type, and reach. A more appropriate approach would use a larger model that included data on multiple species, sample types, or reaches.

***Response:***

First, decisions about the remediation effort will use information on the trends for individual species within each reach. A pooled average rate of change for grouped species is not helpful if it does not apply to each species/reach included. Even if the variation among species' time trends is not significant, pooling them is not advisable if a confidence interval for the variation (interaction effect) is wide, which it is bound to be with a data set of this size and variation. In retrospect, we do agree with the review on one aspect of this point: it may be reasonable to combine sample types for a given species within a reach. It might be reasonable to assume that the time trend parameters would be the same for different sample types. However, the parameter for lipid composition and perhaps the seasonal parameters might need to be different for the different sample types. Such an analysis would also need to address the complicating occurrence that in some cases a fillet was removed and analyzed in the "skin-on fillet" category while the remainder of the same fish was included in the "whole body" category. Any analysis must consider that these two samples were not independent, a complication that could not be dealt with in our analysis, which was carried out when the linkage between specimens was not provided. This issue of combining data from different sample types could be reconsidered if additional analyses are planned.

**RETEC Comment:** More generally, combining either species within a reach or combining reaches for a single species is not advisable for several reasons, as follows. First, species differ in their prey, feeding behavior, and habitat preferences. In several instances, these preferences also change based upon River reach. For instance, a primary forage fish for walleye in OU 4 (De Pere to Green Bay Reach) is the alewife. However, upstream of the De Pere dam, these preferences change because alewife are not present due to the presence of the dam. Secondly, species spawn at different times of the year. Lumping across species does not take into account differences that have or have not occurred due to the well-known phenomenon of material transfer of lipid and contaminants between females and their eggs. Many of these issues are addressed in Technical Memoranda 7a through 7c (WDNR, 1999a, 1999b, 2001), developed as part of the model evaluation efforts and can be found in the *Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (WDNR and RETEC, 2002).

Thus, the biological diversity calls for separate analyses for the different combinations. True, one might use the data itself to determine what combining could be done, but such an effort would quickly founder on the small sample sizes for most combinations. Detecting important differences in time trends for two different species, for example, requires relatively large sample sizes for each. Second, the PCB time trend of each species in each reach is a specific question that a pooled answer cannot give. In short, if there is a sufficient sample size to determine that two sets of samples can be safely combined to calculate time trends, then that very abundance of sample size shows no need to combine. Conversely, combining species or reaches based only on assumptions of similarity simply assumes away real differences that might be profound in a 10- or 20-year forward projection.

Let us consider further what a combined model would involve. Suppose we fit a model that assumes some commonality of time trend parameters. (By "commonality" we mean either the parameters are the same across species or across reaches or have some structure such as being additive in these two factors so that the interactions between these two factors can be left out of the model.) For example, we could combine data from three species within a single reach, and assume that the slopes and breakpoint (if any) are the same for these species. The intercepts could differ, as well as other parameters such as the coefficient on percent lipid, or the seasonality parameters. Such a combined model would result in a single estimate of the final slope for the three species, which may have lower standard error than the estimates for each species separately. If this assumption of common parameters is correct, this strategy would be a good one. However, if the assumption is incorrect, then this model is inappropriate. Theoretically, we can test the assumption using the observed data. For example, we could test whether a model that allows three different slopes for the three species fits the data significantly better than a model that assumes the three have the same slope. However, it should be kept in mind that the power for detecting differences in slope (i.e., an interaction between time and species) will in general, be low. Power will only be high if the sample sizes for each species are large enough to give fairly precise estimates of slope for each species separately, in which case there is not much need to combine them.

Alternatively, we could consider a model with different time trend parameters for each species and reach combination, but that allows some commonality in the seasonal parameters and the lipid composition parameter. This model will still produce separate estimates for each species/reach. We expect these estimates would not be much more precise than the estimates we have already produced. Any improvement would come from using fewer degrees of freedom in estimating the seasonal and lipid parameters. This approach may lead to some improvement in cases with few distinct time points of data collection, so the two degrees of freedom in time used by the seasonal parameters for each species/reach could be important. In any case, the species/reach combinations omitted from our analysis due to small numbers of samples will not contribute much, if anything, to this analysis. In most of these cases the samples were not spread out much over time, so it may not even be possible to fit a set of time trend parameters specific to that species/reach. Thus, we believe a combined model will have only a little more precision than fitting models separately to each reach/species combination, unless it assumes some commonality for the time trend parameters. Models that incorporate such commonality could be constructed but would be a labor-intensive effort requiring much discussion between statisticians and biologists about what kinds of assumptions may be reasonable, followed by testing numerous interactions to see which can be left out of the model. Further, the precision of the interaction estimates is likely to be small, so that major differences among species in, for example, lipid effect on PCB concentration would be missed.

In any case, even if a more efficient use of the data leads to narrower confidence intervals, the issue of model uncertainty remains, i.e., which model should be used to project into the future. We address this matter below (Section B.3.2c).

In summary, we feel that our strategy of producing separate estimates for each species/reach/ sample type is reasonable, and that not much would be gained by building a more complex model that combined data. The exception may be that some precision may be gained by combining sample types within a species for a given reach.

### *B.3.2b Inappropriate Model Used*

***Comment (Paraphrased):***

The breakpoint model is not appropriate: It is a model of convenience with no scientific rationale, it is inherently difficult to estimate and does not have simple statistical properties.

***Response:***

Any model that could be proposed would be a model of convenience. This includes the breakpoint model, as well as the model suggested in the review (Model 4 in Table 1 of this response, Section B.3.2c). The choice of the breakpoint model was driven mainly by the observation that plots (log PCBs vs. time) for some of the sample types show a clear change in the slope, changing from a steep slope early on to a shallower slope later. This change is most apparent in Little Lake Butte des Morts, the reach furthest upstream. Such a break in slope is plausible if the dumping of PCBs stopped in the late 1970s. A rapid decline in PCB in fish shortly after this cessation, followed by a more gradual decline, could be a consequence of such a change.

In contrast to some other potential models, the breakpoint model does not have the constraint that PCB concentrations must be monotonically decreasing over time. As a description of the changes seen in the historical data, this lack of constraint can be a desirable property in that it allows analysis of changes over time without imposing a preconceived notion of when the changes occur. In particular, it reveals that PCB concentration appears to increase in a few cases. Such an increase could be real, for example, due to a scouring event that exposed previously buried sediment with high PCB concentration.

As is pointed out in the review, the breakpoint model can be quite unstable, particularly when the observed data have a nearly linear pattern. In this case, there are two extra parameters and the likelihood surface will be nearly flat in some directions. However, this is also true of any model with four parameters in time, including the sum of two exponentials and the power transform model proposed in the review (Model 4 of Table 1 below, Section B.3.2c). Our decision to use the breakpoint model only when the data manifestly required it avoided some of the instability.

In conclusion, we feel that the breakpoint model is a reasonable choice for describing patterns seen in the historical data. However, the lack of constraints on the breakpoint model means it can give a quite unstable estimate of the final slope. In this context, an "unstable" estimate is one with a wide confidence interval that may change quite a bit in response to small changes in the data. Other models (Table 1) constrain the slope to change only slowly or not at all, and constrain the slope to always be negative or zero. Such models will lead to more stable estimates of final slope and of projected PCB levels in the future. This stability comes from the model assumptions (and not from the data itself), and in particular, the assumptions about what kinds of future patterns are allowed. The stability of the models is bought at the price of faith in (rather than proof of) what kinds of time trends and future behavior are possible.

To achieve the goal of generating predictions of future PCB levels, a somewhat different approach would be appropriate. Discussions with scientists should explore what trajectories of future PCB concentrations are reasonable. For example, is it plausible that PCB concentration could decrease at a fairly constant percent rate per year for a while, but then asymptote to some virtually constant level rather than zero? Based on these discussions, a set of plausible models could be selected and then fit to the data and the resulting estimates could be compared. Of course, any model not consistent with the data would be excluded. For example, the simple exponential model would be excluded if a model with changing slope fit significantly better. As discussed in Section B.3.1 above, we feel this strategy for model selection is better than trying to find the one best, simplest model.

In summary, we feel the breakpoint model is a reasonable model for describing the historical data. It allows a positive time trend for PCB concentration and a negative trend. It provides a test for the presence of a changing trend. The breakpoint model has some undesirable statistical properties, as would be any model with four time parameters. By using the breakpoint model only when the change in slope was substantial, some of the problems in fitting the model were avoided. Other models could be explored for projecting PCB concentrations into the future, and this exercise would show the sensitivity of future projections to model assumptions. We give a brief example of this comparison exercise, below, in Section B.3.2c.

**RETEC Comment:** A break in slope is <u>reasonable given that the discharge</u> of PCBs stopped in the late 1970s (see Technical Memorandum 2d [WDNR, 1999c]). For example, the P.H. Glatfelter secondary wastewater treatment plant did not go online until late in 1979, at which time discharge of PCBs decreased.

### *B.3.2c Reliable Future Projection is Possible*

***Comment (Paraphrased):***

The Mountain-Whisper-Light has incorrectly concluded that future PCB trends in fish and sediments cannot be estimated from the available data.

***Response:***

An important point taught in a linear regression course is the need for great care when extrapolating beyond the range of the observed data. Any extrapolation beyond the range of the available data is based on some assumed model that specifies how the data will behave outside the observed range, for example, that a linear trend will continue out into the future. Such an assumption may be reasonable or even correct, but is still an assumption that cannot be validated with the data on hand. A different assumed model would give a different prediction. Thus, rather than saying "based on these data we predict…" it is more appropriate to say "based on these data <u>and</u> this presumed model for future behavior we predict…"

In addition to random variation in our finite sample, another contributor to uncertainty of future predictions is model uncertainty. We can use a sensitivity analysis to explore this uncertainty due to model selection. A reasonable strategy would be to come up with a few scientifically plausible models and produce estimates of future concentrations of PCB based on each model. The range of estimates, including confidence intervals, from these various models provides a sensitivity analysis for future projections.

To illustrate the importance of model assumptions, we fit three different models to two data sets: carp, skin-on fillet from Little Lake Butte des Morts; and walleye, skin-on fillet, from De Pere to Green Bay. For this exercise, we ignored lipid content and seasonal effect. None of the observations are below detection limits.

The three models are described in Table 1. The table also presents, for completeness, two other models that are not included in the model-fitting exercise. The models which have been fitted to the observed data are: exponential decay (Model 1 of Table 1); exponential decay, but a constant asymptote greater than zero (Model 2 of Table 1); and Dr. Switzer's proposed power transform model (Model 4 of Table 1). Figure 1 shows the fitted curves for carp and Figure 2 shows the fitted curve for walleye.

Table 2 gives the projected median PCB concentration for each model in the years 2010 and 2020. These tables and figures present the point estimates, and do not include the corresponding confidence intervals. It is very clear that the projected future PCB concentration differs drastically depending on which model is assumed. In Figure 1, Carp, the two models with a curved representation in the figure both fit the observed data statistically significantly better than the straight line (simple exponential decay) linear curve. However, in Figure 2, Walleye, the "curved" models do not fit significantly better than the straight line model. Figures 3 and 4, and Table 3 show future projections based on the same data but with observations prior to 1980 excluded. The three models still show different projected concentrations, but not as diverse as for the carp models. We present these plots and tables merely as examples. The models are simpler than those used in our Time Trends Report in that percent lipid and seasonality are not included, and the table shows medians rather than means. A more thorough analysis would include these covariates, accommodate censoring, and compute confidence intervals for the projections.

It is clear from this example that, at least for some combinations of reach and species, different models will fit well over the range of observed data, but differ drastically in future prediction.

### *B.3.2d Declining Trend*

***Comment (Paraphrased):***

The bulk of the evidence supports a clear declining trend in PCBs.

***Response:***

We agree that this pattern is usually apparent in all but the most upstream reach. However, it should be kept in mind that for most species the PCB concentration at the end of the historical data is still quite high. Only if this decreasing trend continues into the future will PCB levels drop below an acceptable level. In the reach that is furthest upstream, evidence indicates that the decline in PCB concentration in fish has flattened out for some species, remaining fairly constant at a level that is still quite high. Will this flattening out occur in the lower reaches at some later time? This question cannot be answered solely by analysis of this data set.

## TABLE 1 DESCRIPTION OF VARIOUS MODELS THAT MAY BE PLAUSIBLE FOR PREDICTING FUTURE PCB LEVELS

| Model | Formula for PCB Concentration | Formula for Log of PCB Concentration | Description of How Rate of Decrease on Log Scale Changes with Time | Comments |
|---|---|---|---|---|
| 1. Exponential decay. (2 parameters) | $\exp(b_0 + b_1 * time)$ | $b_0 + b_1 * time$ | Constant slope (rate of decrease does not change). | |
| 2. Exponential decay, but asymptotes to a constant greater than zero. (3 parameters) | $\exp(b_0 + b_1 * time) + c$ | $\log(\exp(b_0 + b_1 * time) + c)$ | Constant slope for a while, then as value gets low slope flattens out to become zero slope. | Slope can never become positive, but can transition from constant slope to zero slope rather quickly. |
| 3. Sum of two exponentials. (4 parameters) | $\exp(b_0 + b_1 * time) + \exp(c_0 + c_1 * time)$ | $\log(\exp(b_0 + b_1 * time) + \exp(c_0 + c_1 * time))$ | Slope is constant for a while, then smoothly transitions to a less steep slope (or even a positive slope) and then continues at this new slope. | Final slope can be positive; smooth transition from one slope to the other. |
| 4. Dr. Switzer's proposed model. (4 parameters) | $\exp(b_0 + b_1 * [time – a]^{c})$ | $b_0 + b_1 * [time – a]^{c}$ | Slope smoothly and slowly gets less steep over time. | Slope can never become positive, and only slowly approaches zero. |
| 5. Breakpoint model (4 parameters) | $\text{Exp}( b_0 + b_1 * time + b2 * (time-t_0) \bullet [time< t_0] )$ | $b_0 + b_1 * time + b2 * (time-t_0) * [time< t_0]$ | Slope is constant at ($b_1$) after $t_0$, and constant at ($b_2 + b_1$) before $t_0$. | Final slope can be positive. |

**Notes:**

For all models, $b_1$ will be negative if PCB concentration is decreasing. All of the 4-parameter models are unstable to fit when the observed data are fairly linear, because in that case there are two unnecessary parameters.

## TABLE 2A PREDICTED MEDIAN PCB CONCENTRATION (PPB) BASED ON DIFFERENT MODELS – DATA FOR ALL YEARS INCLUDED

### LITTLE LAKE BUTTE DES MORTS, CARP, SKIN-ON FILLET

| Model from Table 1 | | Predicted PCBs in 2010 | Predicted PCBs in 2020 |
|---|---|---|---|
| Model 1 | Exponential decay | 413 | 159 |
| Model 2 | Exponential decay, but asymptotes to a constant greater than zero. | 3,148 | 3,148 |
| Model 4 | Dr. Switzer's proposed model. | 1,290 | 1,038 |

### DE PERE TO GREEN BAY, WALLEYE, SKIN-ON FILLET

| Model from Table 1 | | Predicted PCBs in 2010 | Predicted PCBs in 2020 |
|---|---|---|---|
| Model 1 | Exponential decay | 398 | 216 |
| Model 2 | Exponential decay, but asymptotes to a constant greater than zero. | 867 | 860 |
| Model 4 | Dr. Switzer's proposed model. | 643 | 526 |

## TABLE 2B PREDICTED MEDIAN PCB CONCENTRATION (PPB) BASED ON DIFFERENT MODELS – DATA PRIOR TO 1980 ARE EXCLUDED

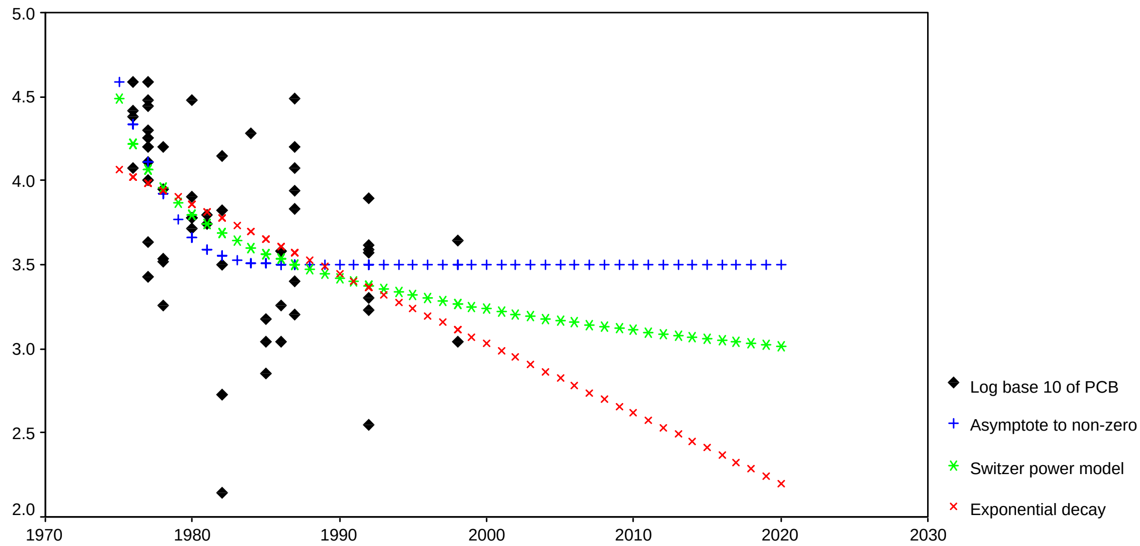
### LITTLE LAKE BUTTE DES MORTS, CARP, SKIN-ON FILLET (EXCLUDE DATA PRE-1980)

| Model from Table 1 | | Predicted PCBs in 2010 | Predicted PCBs in 2020 |
|---|---|---|---|
| Model 1 | Exponential decay | 1,203 | 760 |
| Model 2 | Exponential decay, but asymptotes to a constant greater than zero. | 3,034 | 3,034 |
| Model 4 | Dr. Switzer's proposed model. | 1,790 | 1,564 |

### DE PERE TO GREEN BAY, WALLEYE, SKIN-ON FILLET (EXCLUDE DATA PRE-1980)

| Model from Table 1 | | Predicted PCBs in 2010 | Predicted PCBs in 2020 |
|---|---|---|---|
| Model 1 | Exponential decay | 489 | 303 |
| Model 2 | Exponential decay, but asymptotes to a constant greater than zero. | 1,045 | 1,045 |
| Model 4 | Dr. Switzer's proposed model. | 636 | 516 |

## FIGURE 2 LOG BASE 10 OF PCB CONCENTRATION BY YEAR, PREDICTED BY THREE MODELS – LITTLE LAKE BUTTE DES MORTS, CARP, SKIN-ON FILLET, DATA FOR ALL YEARS INCLUDED




## FIGURE 3 LOG BASE 10 OF PCB CONCENTRATION BY YEAR, PREDICTED BY THREE MODELS – DE PERE TO GREEN BAY, WALLEYE, SKIN-ON FILLET, DATA FOR ALL YEARS INCLUDED

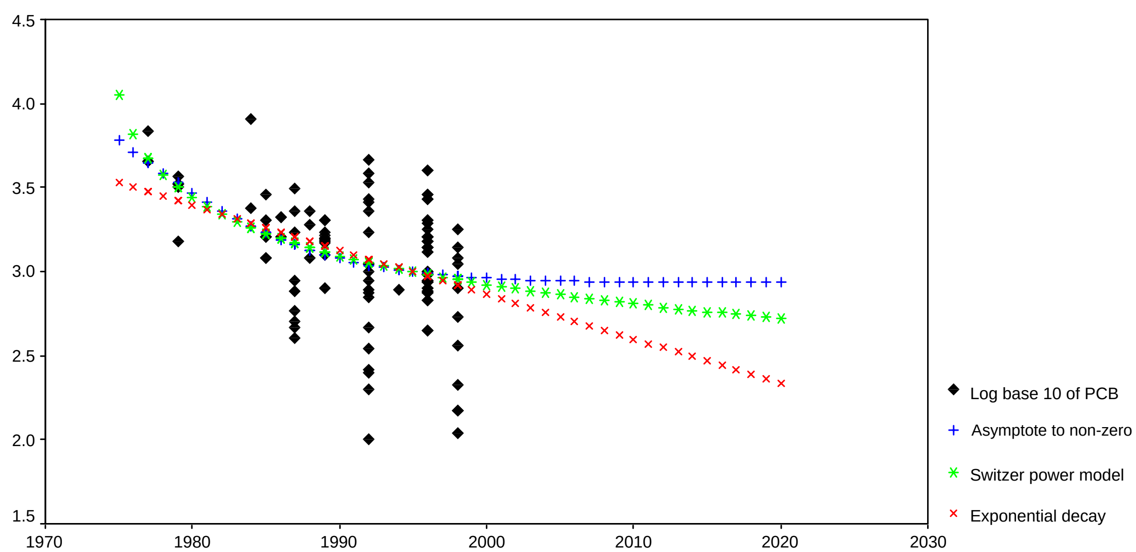


**FIGURE 4 LOG BASE 10 OF PCB CONCENTRATION BY YEAR, PREDICTED BY THREE MODELS – LITTLE LAKE BUTTE DES MORTS, CARP, SKIN-ON FILLET, DATA PRIOR TO 1980 EXCLUDED**

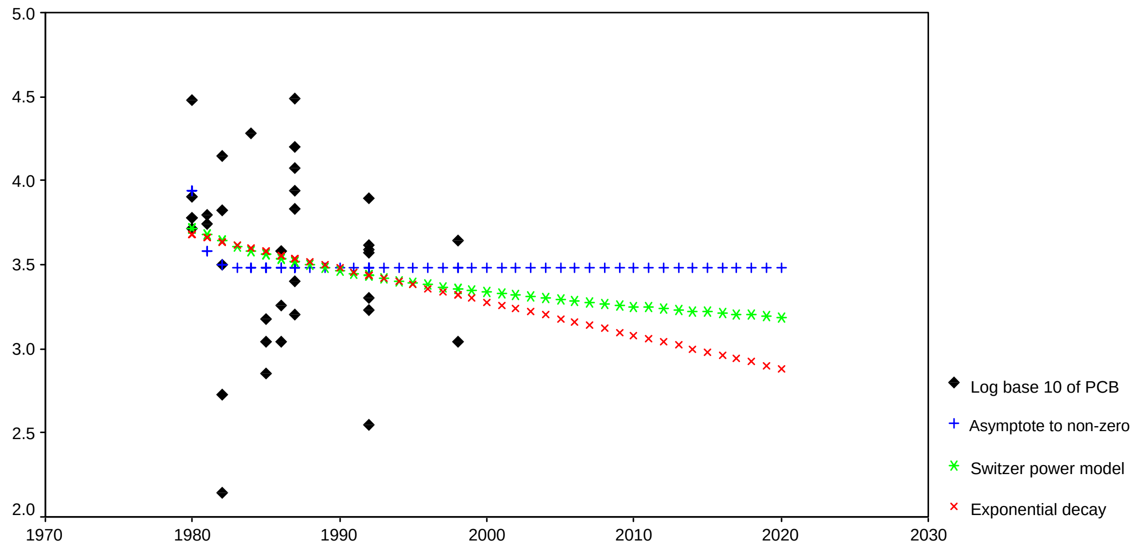
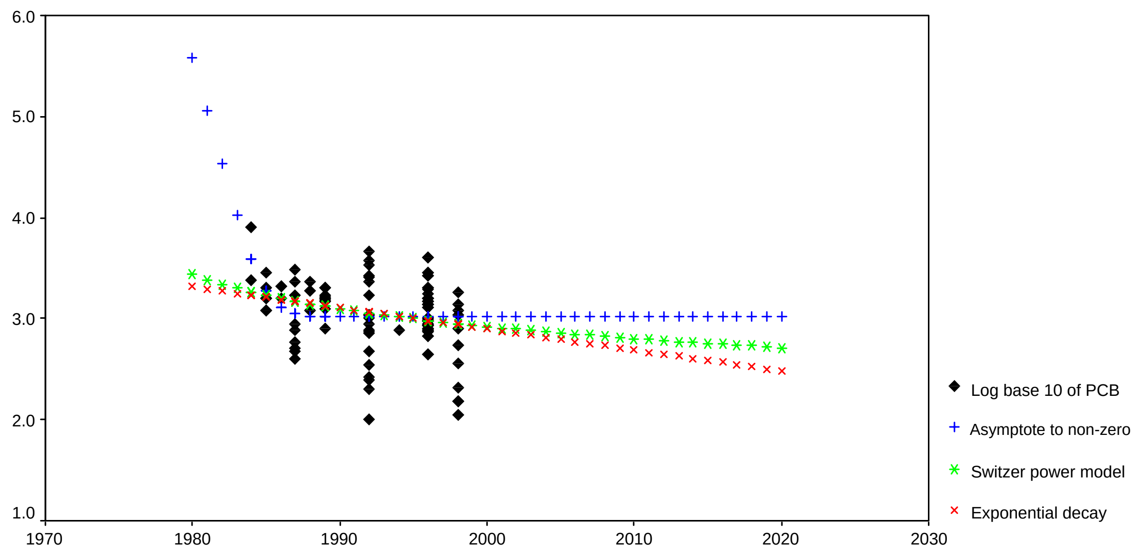



**FIGURE 5 LOG BASE 10 OF PCB CONCENTRATION BY YEAR, PREDICTED BY THREE MODELS – DE PERE TO GREEN BAY, WALLEYE, SKIN-ON FILLET, DATA PRIOR TO 1980 EXCLUDED**



## B.4 RESPONSE TO SPECIFIC POINTS MADE IN THE REVIEW

### B.4.1 Methods for Fish Analysis

#### *B.4.1a Lipid Normalization*

***Comment:***

MWL 2.1 proposes a PCB normalization to account for variations in the lipid percentage of individual fish in the PCB data set. The proposed logarithmic-scale normalization uses an additive linear regression approach, estimated from the data. The assumptions made in the application are that:

a. The lipid coefficient is different for each of the 19 time series selected for analysis.

b. The lipid coefficient remains the same throughout the study period for each time series.

Estimates of the lipid coefficients are typically quite different for different series. While I am not acquainted with physiology of PCB lipid absorption, as a statistician I would ask for a physiological explanation of the differences seen in the adjustment factors. If we see differences where they are not expected, then this suggests some inadequacy in the normalization approach.

Given the relatively few time points available in each time series, it is not unreasonable to keep the lipid coefficient the same throughout the series. MWL did not choose to investigate the possibility of lipid coefficient changes over time in the same way that it investigated changes in the PCB time trend coefficient. Although, in my view this would not be of great importance, looking for time changes in the lipid coefficient would create an interesting perspective for the later breakpoint time trend analysis. Also, there was no investigation of non-linearity of the regression relationship to PCB.

Notwithstanding the foregoing critique of the lipid normalization approach, I consider the shortcomings to be of secondary importance.

***Response:***

Since drawing conclusions about the lipid normalization coefficients was not of primary importance in this analysis, we did not feel it was important to do a more complex analysis, especially if it meant adding more parameters to the model. We also agree that it is reasonable to keep the lipid coefficient constant over time.

#### *B.4.1b Seasonality*

***Comment:***

MWL 2.2 proposes adjusting the PCB data for seasonal variations related to time of year in which the PCB data were collected. If there were sufficient seasonal variability in a PCB time series, then such an adjustment would be reasonable and could be estimated from the data. The seasonal adjustment would give added precision to the time trend coefficient estimates in such favorable cases. However, with insufficient seasonal variability in a series, the PCB time trend coefficient could be degraded by an unsuccessful attempt to fit a seasonal adjustment.

***Response:***

Seasonality is statistically significant and is a large effect for many of the time series, so we feel it is important to include it, both to improve precision and to avoid possible bias that might arise from its exclusion. For some time series, the season in which samples were taken differed over the years. We agree that for some series with only a few distinct time points, having seasonality in the model may mean that the model includes almost as many parameters for time as there are distinct time points. This situation leads to unstable estimates and is the reason we excluded time series with too few distinct time points. Nevertheless, this issue still affects a few of the time series since we may have been too generous in including series with sparse data. Our contention is that if there is insufficient variation in time to fit a model with seasonality, it is not appropriate to therefore leave seasonality out of the model. Rather one should conclude there is insufficient data to fit the correct model and not analyze that series. Also, see our comment on the BBL analysis in Sections B.8 and B.9, where we note that the time trend estimate may be biased by ignoring the seasonal effect.

***Comment:***

The time of the year corresponding to the largest fish PCB values is found to be different for different series, even for the same reach and species. For example, the estimated peak PCB time for carp skin-on fillet is the year-end, while the estimated peak for carp whole body is mid-year. This illustrates some of the paradoxical statistical estimates that one gets from routine statistical analyses that do not take account of biological constraints and consistency.

Notwithstanding the above criticism, I regard the sometimes anomalous season adjustments not to be a primary concern in relation to other issues.

***Response:***

WDNR fish biologists do not support the assumption of common seasonal peaks across species or reaches. However, a combined model, if plausible, could lead to a small improvement in precision of estimates.

**RETEC Comment:** As stated previously, maternal transfer of contaminants between females and their eggs and the presence of species that spawn in spring (walleye), late spring/early summer (white bass), and summer (carp), is but one example of biological events that warn against lumping across species. As also stated previously, the differences between potential exposure as a result of numerous PCB entry points into the River and the changing conditions within a River reach, advise against lumping across River reaches.

### *B.4.1c Time Trend Models*

***Comment:***

Two time trend models are considered in MWL 3.3, one with a constant trend and the alternative with a trend that changed abruptly at some breakpoint during the observation period. The trend models are compared separately for each of the 19 selected series, and the breakpoint model is used for further analysis if a better fit can be detected statistically for the breakpoint model.

The purpose of introducing the breakpoint model was presumably to capture features of the PCB time trend that are changing with time, and to provide future projections that account for the change. The breakpoint model was an unfortunate choice for several reasons:

a. No argument is given why there should be an abrupt change in the behavior of the trend at a particular time.

b. Breakpoint estimates have poor statistical precision.

c. Best-fitting estimates of breakpoints vary substantially from one series to another.

d. The breakpoint model adds two additional parameters, which is an issue given that the observations in a series are typically restricted to only a handful of distinct years and are typically not evenly spread over the observation period.

e. It appears that the breakpoint model is merely one of convenience for detecting a changing time trend. It would then be inappropriate to use such a model of convenience for future projection of PCB trend.

The motivation for the breakpoint model was given in Section 3.3 of the Time Trends Report.

There are alternative models that allow for a changing trend over time but that do not suffer from the instability and implausibility of breakpoint models. For example, a monotonic time trend model of the form $b_1\ [time - a]^c$ would allow for trend that varies over time without relying on a single abrupt change and would provide more meaningful future projections because of the evolutionary nature of the time trend both before and after the observation period. The model uses the same number of parameters as the breakpoint model. The shape parameter $c$ has a value between 0 and 1, estimated from the data. $c = 1$ corresponds to a constant time trend model, $c = 0$ corresponds to unchanging PCB values. The parameter $a$ corresponds to the time at which PCB concentrations started to decline, and can either be an estimated parameter or a fixed parameter. The model can be estimated by non-linear least-squares and can be used for future projections. (Neither this power-law model nor the breakpoint model should be used for increasing PCB trends.)

In summary, the breakpoint model is an implausible model of convenience with parameters that are poorly estimated. We regard the breakpoint modeling choice as a serious mistake.

***Response:***

See Sections B.3.2b and B.3.2c. The model presented by the reviewer (slightly modified) can be considered as one of the several plausible models for projecting future PCB patterns. We would like to point out several aspects of this model. First, it constrains how quickly the rate of decline can change, so that if the rate has been changing only slowly during the historical time series, this model predicts that it will change only slowly in the future. This aspect contrasts to models 2 and 3 in Table 1, in which the rate of decline can change fairly rapidly in the future even if it has been fairly constant in the past. That is, model choice largely determines future predictions. This model has four parameters – the intercept term $b_0$ was accidentally left out in the reviewer's paragraph, above. Fitting all four parameters gives a very unstable fit because the likelihood will be almost flat in one dimension unless the observed time series shows a very pronounced curvature. In the example fits shown in the figures and in Table 2, we fixed the parameter "*a*" to be 1974 to be able to fit the model. In this power-law model, as the parameter "*c*" goes to zero the transform goes to the log transform. In the family of power-law transforms, negative values of "*c*" could be allowed, which would allow even greater curvature than does constraining "*c*" to be positive. And, in fact, in our initial fits of this model to carp, skin-on fillet in Little Lake Butte des Morts, we did not impose a constraint on "*c*" and the estimated value turned out to be negative.

The breakpoint model permits positive rates of increase, whereas the reviewer's model does not. Among all the models considered in Table 1, for those that allow a changing slope, only the breakpoint and combined exponential models, (3) and (5), respectively, permit a positive slope. Models (3) and (5) would have properties fairly similar to each other. Which of these models is most "plausible" is a question for scientists to answer, not statisticians. As was discussed earlier, in Sections B.3.1 and B.3.2, we would consider all of these to be "models of convenience."

### *B.4.1d Model Fitting and Hypothesis Testing*

***Comment:***

It was argued in MWL 3.4 that the breakpoint model allows the use of simple linear methods. But having to estimate the breakpoint location cancels the ability to use linear model theory to get estimates of precision, and estimates based on linear models are irrelevant. Thus, the standard errors associated with rate parameters in breakpoint models are meaningless as given because they are derived from linear model analysis.

***Response:***

The standard errors are not meaningless. They provide lower bounds on what the correct standard errors would be in an analysis where the breakpoint and slopes are estimated simultaneously in a single step. Thus, the projections into the future based on the breakpoint model would have more uncertainty than shown in our Time Trends Report.

***Comment:***

Breakpoint times were allowed that had only 2 years of data beyond the breakpoint, thus effectively estimating a final time trend from 2 years of observations.

***Response:***

We did allow models with only 2 years of data beyond the breakpoint so as to detect a change in slope that occurred late in the time series. The final estimated slope is then quite unstable, but the finding of a breakpoint is important. See response C about projecting into the future (Section B.3.2c).

***Comment:***

MWL did not use standard statistical methods to analyze parameter uncertainty in its breakpoint analysis. The breakpoint sensitivity study does not substitute for a statistical analysis. MWL argued that a statistical analysis, for example using bootstrapping, would require too many resources. This is not likely. If one is trying to estimate a fundamentally nonlinear model, one should expect to do the extra computing associated with the estimation. However, see my earlier remarks regarding the basic instability of the breakpoint model. Computing resources should, instead, be devoted to estimation with a more plausible class of models that are better adapted to future projection.

***Response:***

If resources and time are available, it would be best to compute standard errors based on fitting the breakpoint and slopes simultaneously. However, the sensitivity analysis <u>does</u> yield an interval of plausible breakpoints, and outside of the interval, the breakpoints are much less plausible. We recommend defining a set of plausible models based on scientific judgment, then examining how much results differ depending on which model is assumed. The exploration of alternative models could be carried out in an expanded study with additional resources.

***Comment:***

In summary, a full statistical analysis of the breakpoint model was not done, and reported confidence ranges for trend parameter estimates will not be correct.

***Response:***

The reviewer is correct. The standard errors of slopes are underestimated, and the future projections will have confidence intervals that are not wide enough. The uncertain future of the River will be more uncertain than that noted.

### *B.4.1e Testing for a Constant versus a Changing Final Slope*

***Comment:***

Within the context of the breakpoint model, MWL 3.5 proposes checking whether the rate of PCB change, after the breakpoint only, is itself changing with time. This is done by fitting an extra parameter for curvature of the trend. Once again, the analysis ignores the uncertainty of the breakpoint time, that would prevent drawing conclusions. Furthermore, the analysis relies only on the relatively few PCB data after the estimated breakpoint to estimate a model with an extra parameter. Finally, any claimed curvature of the trend could not be used for purposes of future projection because of the nature of the fitted model.

***Response:***

The analysis is carried out conditional on a selected breakpoint (if there is a breakpoint). While the quantitative conclusions will depend on where the breakpoint is placed, the analysis can be viewed as a way of looking at late slopes to determine if the River is going to change again. Thus, conclusions can be drawn, but they must be stated with the condition of the selected breakpoint, for those analyses that include a breakpoint. As to relying on the "relatively few PCB data after the estimated breakpoint," indeed, some of the analyses have limited power due to the limited amount of data available. As usual, lack of statistical significance cannot be interpreted as absence of curvature, but statistical significance would be evidence for curvature. This was the appropriate interpretation that we applied to this analysis. The limited sample size encountered throughout this study, and many analyses, does not prevent analysis, but requires an appropriate interpretation of slopes and standard errors and statistical significance. We followed this proper procedure in handling the limited sample size. Concerning future projection, we do not intend in any way to use the quadratic model for future projection, as we made clear in our Time Trends Report. The quadratic models are used only for hypothesis testing and not for predicting the future. Thus, the fitted quadratic model summarizes the more recent data and determines if there is evidence that the slopes are changing during this later period (and thus might be changing again in the future). The quadratic model estimates are not used for future projection, which is evident from the Time Trends Report.

### *B.4.1f Meta Analysis – Combining Data on All Species Within a Reach*

Some of the criticisms of our meta-analysis are valid. The meta-analyses were not a crucial part of the Time Trends Report – their main purpose was to support the analyses of individual species within reaches. If the meta-analyses were removed from our Time Trends Report, it would not change the general conclusions.

***Comment:***

MWL 3.6 describes methods for combined meta-analyses that pool all the trend information obtained within a geographic region, regardless of species and types.

Three hypotheses are described in MWL 3.6. The first hypothesis is that a linear model without breakpoint fits as well as a breakpoint model, for all time series in the given reach. However, rejection of this hypothesis, which is the presumed goal of the analysis, does not resolve the issue of whether just one series shows a breakpoint, or whether it is a general pattern. Thus, this combined test is not useful for drawing general conclusions about changes in PCB time trends.

***Response:***

The meta-analysis of breakpoints does establish that breakpoint(s) are present, and it supports the individual reach/species analysis. It is not a major point. The meta-analysis properly supports other conclusions.

***Comment:***

The second hypothesis is that the final true time trend is zero for all time series within the reach. This is an unlikely hypothesis on its face, and formal statistical tests are really not needed to show that at least one series has declining PCB values.

***Response:***

Again, it is a small but helpful addition to the proceedings.

***Comment:***

The third hypothesis is the final true time trends are all linear. Rejection of this hypothesis would indicate that at least one of the component time series had a final time trend that was not linear, a rather weak statement. As in the case with the first hypothesis, the overall meta-analysis test can be decided by a single time series that shows a sufficiently strong non-linearity, even if the others are all perfectly linear, making it difficult to draw general conclusions on the basis of the meta-analysis.

***Response:***

There is so little power in each individual analysis to detect non-linearity that a meta-analysis makes sense to gain power. While the conclusion may not be sweeping, the presence of non-linearity is worth noting.

***Comment:***

Meta-analysis is also used to pool the PCB time trend estimates for all species/types within a reach, to get an overall trend estimate. Such a meta-analysis could be meaningful if one assumed that the time trend parameters should indeed be similar for all species/types, and that only the limited data for each separate series makes the time trends look different. Presumably, separate analyses were done in the first place for different specie/types because similarity of PCB time trends was thought to be unlikely. It now becomes difficult to interpret the combined trend estimate. The analogy with an overall economic growth rate as a combination of sector growth rates is inappropriate here because the overall rate is obtained by meaningful weighting of the relative sectors according to their respective contributions to overall economic activity. The analogy is more appropriate to meta-analysis of sediment trends, but not to fish.

The combined meta-analysis trend estimate is obtained as a weighted average of trend estimates from individual series, with substantial weights given only to species/types with the smallest standard error estimates for trend. There are two problems with this weighting scheme – first, the standard errors do not account for breakpoint estimation for those series with breakpoints, and second, the meta-analysis estimate could be dominated by a single series, in principle, because of the underlying homogeneity assumption. MWL did not do any tests for homogeneity as part of its meta-analysis, although such tests may have low power.

In summary, the meta-analyses are not meaningful unless some homogeneity is assumed. Furthermore, they do not test relevant hypotheses, they use weights that do not reflect the relative importance of the different species/types, they do not explore issues of heterogeneity, and they lead to combined estimates that are difficult to interpret.

***Response:***

We agree that the fish meta-analysis (for a pooled linear trend) has a degree of arbitrariness to it, but it generally confirms the negative trends observed during the period of data collection.

### *B.4.1g Projecting into the Future*

***Comment:***

MWL 3.7 describes a method for projecting the final linear time trend for each of the 19 series. Confidence interval formulas are given for predicted values that do not take account of the breakpoint uncertainty for those seven series that use breakpoints.

***Response:***

Correct. The confidence intervals are not wide enough. Confidence intervals are also too narrow for the other series in which we accepted the linear model rather than the breakpoint model, because they do not account for the fact that a non-linear model (the breakpoint model or some other) is also compatible with the data. See issue C. The story remains unchanged, however: the future is difficult to predict.

***Comment*:**

It is not clear from the description whether the formula of Equation 9 uses statistical estimates that account for the presence of seasonal and lipid adjustments in the model.

***Response:***

Projections into the future are based on fixing (at zero) the values of the three <u>centered</u> covariates (lipid, sine, and cosine of day of year). Because these variables were all centered, zero for centered lipid is the mean lipid in this particular sample, and, for the centered seasonality variables, zero means July 1. Thus, the variances and covariances of the coefficients on these covariates play no role at all in computing confidence intervals on future projections.

***Comment:***

Equation 11 is used for estimation of time to reach a specified concentration. However, confidence intervals for these estimates were not obtained because MWL claimed that "would seriously complicate our analysis." Modern statistical and computing methods provide straightforward tools for getting confidence interval estimates in almost any problem, under the assumptions that have already been used.

***Response:***

Yes, given the resources, such confidence intervals could be computed. However, the confidence intervals on PCB concentration at a fixed future date is so much easier to compute that we decided to show only those as a measure of the uncertainty of future projections. Because the confidence intervals are so wide for this method, confidence intervals for time to reach specified values would also be very wide.

***Comment:***

In summary, there are possible errors in this section that need to be corrected and analyses that need to be completed. Accounting for the uncertain breakpoint in future PCB projections could be avoided by using smoother time trend models. Corresponding projection uncertainties could be quantified without the unmanageable uncertainty of a breakpoint analysis.

***Response:***

The points have been raised earlier and individually addressed. The only "error" is an underestimate of slope uncertainty.

## B.4.2 Fish Results

### *B.4.2a Number of Observations*

***Comment*:**

The criteria used in MWL 5.1 for selecting fish time series for inclusion seem somewhat arbitrary and resulted in elimination of about one-half of the available data. For example, there is no particular reason why the minimum number of observations needs to be exactly twice the number of time parameters, i.e., the 14-observation minimum for an included series. The criterion of "sufficient variation in time" seems reasonable as a general idea, but the operational criterion has not been described. An example of an explicit criterion of this type might be to have at least two observations in each 5-year period. Unspecific and ad hoc criteria for data inclusion invite speculation regarding purposive selection to reach particular conclusions.

***Response:***

Some criteria were clearly needed, and whatever ones are chosen will, of necessity, be arbitrary. Our criteria were determined a priori before data analyses were done, and were not selected to support a particular conclusion. Inclusion of smaller data series would only have added more cases with very low power for detecting non-linearity, and wide confidence intervals on slope estimates. In retrospect, we may have been too generous with respect to including time series with only a few distinct time points. In our Time Trends Report, we pointed out that this caused a problem in one series, yellow perch in Green Bay Zone 2. This problem also may be an issue in a few other series.

***Comment:***

If the modeling had been more flexible, then fuller use could have been made of the available data with less of the arbitrary data selection. For example, instead of trying to build a separate independent model for every reach, species, and type combination, one could use a combined model in which model parameters are themselves expressed in terms of simple functions of reach, species, and type. For example, the PCB linear trend parameter could be expressed as a sum of components that respectively adjust for reach, species, and type. Using a parsimonious modeling approach of this kind, essentially all the data could be used, and it would even be possible to introduce interaction terms into the model. Further, it would be possible to test for common parameter values with the goal of merging species or types.

***Response:***

See Section B.3.2a. We strongly disagree that essentially all the data could be used. This would be true only with a willingness to make extremely strong assumptions about the commonality of parameters, assumptions that cannot be adequately tested because of poor power. Whether such assumptions are warranted is a scientific question, not a statistical one.

***Comment:***

The other data issue is the one of data autocorrelation. It appears that multiple observations were sometimes clustered close together in time, for example for various species/type combinations in Reach 4. It is likely that the PCB variations, for time-clustered observations, will be correlated. The MWL analysis treats all observations as having independent residuals, whether they are clustered or not, with the result that the effective number of independent observations is overstated in such cases. There is no simple way to correct for this data autocorrelation, although a conservative approach is to replace clustered data by a single average value.

***Response:***

This concern is valid, especially if the samples taken on one day were all from a small geographic area. If they were spread over a wide area, then some mechanism would be needed to generate this autocorrelation. An example of a possible clustering effect is seen for carp, whole body, in De Pere to Green Bay (see Figure A-97 in our Time Trends Report). In 1998, 10 samples were collected on July 2 and 11 samples were collected on July 6. The median PCB concentration for these 21 samples was 13,000 ppb, and all but one sample was above 6,000 ppb. Just a few days later, on July 8, 10, and 17, the six samples taken had a median PCB concentration of 1,500 ppb with only one sample above 5,000 ppb. An ANOVA on the log scale shows a highly significant difference in PCB concentration across these 5 days. This issue should be discussed with the scientists to try to understand why such differences across neighboring days could occur. In any case, such clustering is one more reason for believing that the confidence intervals on estimated parameters are not wide enough and that future projections are even more uncertain than we estimated. This clustering effect would also widen confidence intervals for the BBL report's future projections.

Another effect of clustering would be that the hypothesis tests of the null hypothesis of exponential decay versus the alternative of the breakpoint model would be anti-conservative. That is, the *p*-values for testing whether a breakpoint exists may be too small.

***Comment:***

In summary, the issues of data selection are important. The database was substantially and unnecessarily reduced because of the nature of the split analyses that were used. Data selection can severely reduce the power of the analysis, and can even raise questions regarding objectivity.

***Response:***

As covered repeatedly, the selection was necessary to address units of interest for remediation (species by reach) and to eliminate data sets that would be futile for analysis. As for objectivity, the data are of public record (on a website) and anyone can review our selection and the data not selected. The selection is presented in our Table 12 on page 5-2 of our Time Trends Report.

### *B.4.2b Testing Spline Models versus Simple Linear Model*

***Comment:***

It would be fair to say that, in principle, no time trend is ever perfectly linear, i.e., that given sufficient data one can eventually reject the linear time trend hypothesis. Therefore, the real issue is not whether the trend is linear or not, but how far the trend is from linearity. A more appropriate analysis than the one presented in MWL 5.2.1 would have concentrated not on hypothesis testing, but rather on the estimation of degree of non-linearity. Unfortunately, the breakpoint models are not especially suited to this kind of estimation, as discussed earlier.

The spline or breakpoint model is a generalization of the linear model that adds two additional parameters for fitting the data. The computed likelihoods that are needed for the statistical test are based on the assumption of mutually independent observations in the time series data, which ignores data clustering issues discussed earlier. Except for Reach 1, the hypothesis testing framework found that the occurrence of non-linearity in the time trend was uncommon. Even where the breakpoint model was selected for Reach 1, the final trend slope is generally poorly estimated and of little value for projection.

The breakpoint model can produce best fits that are implausible, as seen dramatically in the case of the fitted trend for yellow perch fillet in Reach 5. The breakpoint model was wisely discarded in this case, although the "overfitting" and implausibility argument could have been applied as well to other series such as whole walleye from Reach 1. For this latter series, one should be especially concerned about giving too much weight to the final cluster of potentially autocorrelated observations.

Where straightforward linear time trend models were used, the resulting estimates of annual PCB decline rates were reasonable and had moderately good precision, indicated by smallish nominal standard errors. On the other hand, poor estimates of final trend are typically associated with the breakpoint models. An important and repeated misinterpretation is that the poor estimates of trend in such cases are somehow inherent to the data, rather than being a consequence of the breakpoint model itself. This point is illustrated by referring once again to yellow perch fillet in Reach 5, where the nominally better fitting breakpoint model was discarded in favor of the simple linear model – the "better" model would have given the impression of a poorly estimated final trend, which is not the case for the linear model fitted to the same data.

***Response:***

If it is fair to say that the imprecision in estimates of final trend are not inherent in the data itself but are a consequence of the breakpoint model, then it is equally fair to say that precise estimates of final trend produced by the linear model or Dr. Switzer's model are not the consequence of the data but rather of the model. That is, if one has a precise estimate of the final trend (and by implication what the trend will be into the future) it is because the model assumes that the final trend (and future trend) is the same as the early trend, or that trend changes only slowly. If one is willing to contemplate the possibility that the slope in the few years before 1999 or the few years after 1999 could be quite different from the slope earlier, then the imprecision of estimates of late slope is inherent to the data. Even if one fails to reject the null hypothesis of a constant slope, it is not appropriate to interpret this as proof that the null hypothesis is true and construct confidence intervals based on a linear assumption. That is, the slope estimate from the linear model will be too precise as an estimate of final slope because they do not account for the fact that the data are also consistent with a late changing slope.

***Comment:***

I was puzzled by the estimates of the seasonal correction factor. While the correction factor does seem to reduce the residual error by an appreciable amount, it is surprising that the season for peak PCB concentrations seems to be different for different species and types, as well as for different reaches. There is no discussion of why this might occur or whether there might be some confounding artifact.

In summary, the comparison of linear models with breakpoint models suffers from difficulties associated with poor parameter estimates for breakpoint models.

***Response:***

As the seasonal effect is significant in many of the time series, we feel it is important to include seasonality as covariates in all analyses, especially because the season in which samples were taken varied in different years. Leaving seasonality out of the model would not be an acceptable 'solution' to the 'problem' of differing seasonal peaks. Unfortunately, this means that a breakpoint model has six parameters in time to estimate – initial slope, intercept, change in slope, location of breakpoint, and two seasonal parameters. If the number of distinct time points is only a few more than six (e.g., eight) then the time parameter estimates will be very unstable. This is a limitation of the data; with such data, it is difficult to determine whether rate of decline is changing over time, even if a different model from the breakpoint model were used for this purpose. We were generous by including time series in our analyses, and in retrospect perhaps overly generous, including a few time series that produced unstable estimates due to sampling of too few distinct time points.

### B.4.2c Best-Fitting Model, Meta-Analysis, Sensitivity Analysis, and Future Projections

***Comment:***

The meta-analysis in MWL 5.2.2 combines the information from all time series in a reach to obtain an overall estimate of a final time trend for that reach. Individual time series are often short on data relative to the number of parameters and therefore do not provide precise parameter estimates, whereas a combined estimate has greater precision. The issues here are the interpretation of the combined estimate and the selection of relative weights to be associated with the individual time series. A more meaningful approach, for example, can be had via a hierarchical model that has an overall parameter for trend for the reach as a whole, with different trend manifestations for different species and types. Then the overall parameter has an interpretation and the weighting issues are subsumed in the analysis of the hierarchical model. The overall trend estimate, with its overall precision, might not be too different from what was obtained by the meta-analysis, but this would require further study. It would be possible to use the combined reach parameter to project overall PCB time trends for each reach.

The sensitivity study reported in MWL 5.2.2 looks at how final time trends, for series deemed to have breakpoints, are affected by the position of the breakpoint. As discussed above, the breakpoint position can vary substantially without strongly affecting the likelihood of the data under the breakpoint model, hence creating a wide range of possible final trend values, as can be seen in Table 20. This is an undesirable property of the breakpoint model. The wide range of possible final trend values is a characteristic of the breakpoint model and is not an inherent property of the data. Statements that the final trend was not significantly different from zero, such as that for whole carp in Reach 4, should be read with caution in light of the sensitivity of trend estimates in the breakpoint analysis.

When using a model, fitted to historic data, for projecting future PCB concentrations, there will be inevitable uncertainty that increases as the time horizon moves further away. The reported range of uncertainty is very much tied to the analysis model. Because of problems with the indeterminacy of breakpoint models, they cannot be confidently used to associate a measure of uncertainty for future predictions. The ranges for future projected PCB concentrations should not be taken seriously for those series where a breakpoint model was adopted.

***Response:***

We would accept this conclusion if it is expanded: "The ranges for future projected PCB concentrations should not be taken seriously for <u>any</u> model, because these ranges do not incorporate the likelihood that the model assumptions are wrong." This lack of confidence in future projections is inherent in the task (projecting beyond the range of the data) and inherent in the data (there is insufficient data to precisely estimate rate of decline in the few years just prior to 1999 using only data from those few years). See Section B.3.2c. Any future projections will strongly depend on the precise assumptions about how the slope can change in the future (i.e., future projections will depend more on the model assumed than on the data). This is especially true with the relatively short time series and small sample sizes dealt with in the Time Trends Report. Though it is true that estimates from four-parameter models (models 3, 4, and 5 in Table 1 of this review) have greater problems with indeterminacy than do three-parameter models (model 2 and model 4 with parameter "*a*" fixed), the problem is not with the breakpoint model, but with inadequate data and attempting the inherently risky task of projecting beyond the range of the data, given possible non-linearity.

***Comment:***

Even for a series with an obvious linear time trend, the uncertainty associated with the future will still grow as the horizon recedes and the uncertainty will eventually encompass the no-decline scenario. For this reason, one should be careful about the interpretation of computed PCB prediction ranges for times very far into the future.

***Response:***

The reviewer is incorrect that projections based on a linear model will eventually encompass the no-decline scenario. For model 1 in Table 1, as time goes to infinity, the upper bound of the confidence interval goes to approximately $b_0 + b_1 * time + 2 * s_1 * time$, where $s_1$ is the standard error on the estimate $b_1$. So if $b_1$ less than $-2 * s_1$ (i.e., significantly less than zero), this upper bound will continue decreasing to infinity. The reason to be cautious about projecting far into the future with a linear model is <u>not</u> that the confidence interval gets wide, but rather that it does not get wide enough. The confidence interval is based on the <u>assumption</u> that linearity continues to infinity, and it does not account for the possibility that the curve may become less steep in the future. The same argument given just above applies here. Even if there is no statistically significant evidence of non-linearity in the historical time series, if one is willing to contemplate that a change in slope is possible, then projecting more than a very short time into the future is risky. We would argue that evidence for non-linearity in some of the time series analyzed requires consideration of the possibility of changing slope for all of the series.

***Comment:***

MWL points out that estimates of time trends could change substantially if only a couple observations were removed from the analysis, such as with whole carp in Reach 1. This lack of statistical robustness is severely aggravated with breakpoint models, and it is a serious criticism.

***Response:***

We believe that this lack of robustness would apply to any four-parameter model, perhaps less to three-parameter models. For small, sparse data sets, the only way that an analysis will <u>not</u> have this problem with poor robustness is if one makes that very strong assumption of exponential decay (i.e., constant slope).

***Comment:***

The attempt to fit models with a common breakpoint at 1985 certainly makes the analysis more parsimonious and removes the question of sensitivity to a breakpoint estimated from the data. On the other hand, there is still a breakpoint in the model with the result that final time trend estimates are often apparently much less precise than the estimates obtained directly from the linear model, as seen in MWL Table 23.

***Response:***

This approach should be compared to that in the report by BBL, in which all data prior to 1980 were discarded and then linear models fit to the remaining data. We, in fact, contemplated such an approach, but decided that greater precision is obtained in the post-breakpoint slope estimate by including pre-breakpoint data, with a different slope, rather than discarding such data.

***Comment:***

The tests for "curvature" of the time trend show little statistical evidence for such curvature in the 19 tested time series, as seen in MWL Table 24. The combined hypothesis test indicates that at least one series has a nonlinear time trend, which is not a particularly useful conclusion. The conclusion that the report draws, "collective evidence is that slopes tend to be non-constant," is a misinterpretation of the results of the hypothesis test. As remarked here earlier, it is fair to assume a priori that time trends are nonlinear, but the relevant question concerns the degree of non-linearity, if any, that can be inferred from the historical data and its effects on future prediction. The discussion and rationalization of positive and negative curvatures in this section is confusing and far-fetched.

***Response:***

In retrospect, we could have used a quadratic term to test non-linearity as an alternative to the breakpoint model, rather than using it to test for non-linearity in the post-breakpoint period. The data are really inadequate to support accurate modeling of the post-breakpoint "curvature" for a given reach and species. We would still need the breakpoint model or some other model that accommodates changing slopes in order to provide future projections.

The reviewer's notion of estimating the magnitude of curvature would need much more data than that provided. The meta-analysis and discussion of curvature was carried out to glean something from the analyses collectively that could not be obtained individually.

### *B.4.2d Conclusions about Trends over Time in PCB Concentration in Fish*

***Comment:***

MWL 5.3 concludes reasonably that "the majority of fish categories have data consistent with only a simple linear trend." However, the conclusion about the collective evidence for non-constant time trends is a misinterpretation of the combined hypothesis test of the preceding section, as commented earlier. The statement that "we cannot project into the future with precision" seems mainly to result from the sensitivity of the breakpoint model for estimating final time trends. The ability to project for a decade or two would be helped by a more thoughtful model framework and more complete use of the available data, as outlined here earlier. Where simple linear models were adopted in this Time Trends Report, the projections have modest but usable precision. The precision of projections would be helped further by a combined modeling approach that treated time trends for reaches, species, and types in a comprehensive framework, rather than by data splitting.

***Response:***

See discussion in Sections B.3.2a, B.3.2b, and B.3.2c.

### B.4.3 Time Trends Report Discussion Section

#### *B.4.3a Time Trends Discussion*

***Comment:***

The discussion in MWL 6.2 revisits the discussions contained in earlier chapters. There is repetition of the earlier claim that the fish analysis exhibits changeable time trends. The implication is that changeable time trends are the rule, and that projections are therefore impossible. While I do not disagree in principle with the possibility of changeable time trends, it should be noted first that 12 of the 19 fish time series did not show significant departures from a constant time trend. Second, projections can and should incorporate the evidence and direction of a changing time trend where appropriate; there is no need to write off the whole exercise.

***Response:***

See Section B.3.2c and also the discussion above in the preceding subsections. Again, the model assumptions outweigh the data analysis as future time progresses.

***Comment:***

This discussion also revisits the meta-analyses that combined information from several time series. I generally favor this kind of combination, of fish types for example, as a means of increasing precision of constant or non-constant time trend estimates. However, the meta-analyses were used specifically to test a null hypothesis that none of the component series has a changing time trend. The rejection of this hypothesis could still imply that a changing time trend is exceptional rather than ubiquitous, as is implied in this section. In general, the interpretations of hypothesis testing have been stretched, in this chapter and elsewhere, beyond their true implications.

***Response:***

Changing time trends are a feature of these data as shown by the detection of breakpoints and curvature. A breakpoint or curvature makes future projection uncertain because of the possibility of future changes.

***Comment:***

It is notable that this section makes the important point that "error in the projection is likely to be smaller, when one aggregates the results of projections of individual deposits into larger geographic units." The corollary is that individual projections will have insufficient precision and they should not be the subject of interpretations, contrary to what was frequently done.

***Response:***

If the reviewer wishes to change "insufficient" into "less" and drop everything after "precision," we will agree about the corollary. Without the changes, it is an unsupported assertion.

### *B.4.3b Sources of Uncertainty in the Time Trends Analysis*

***Comment:***

The main issue in MWL 6.3 is the attempt to make distinctions between adequate and inadequate estimates of the individual time trends that were separately and independently computed for the plethora of combinations considered by MWL. In the first place, an important source of the MWL-attributed inadequacy lies in the inefficient use of the data via a modeling strategy that splits the available data, especially for sediments. Secondly, MWL sets the dividing line for trend estimation adequacy in terms of 5% significance for a particular null hypothesis, a procedure that does not take into account the actual needs of the decision making process. Even relatively wide range for projected PCB may still provide useful information for planning purposes. Third, the fine splitting of the data detracts from the bigger picture that a combined analysis provides. For these reasons little useful information is conveyed by MWL Table 31 and Table 32.

***Response:***

The intention of Section 6.3 of our Time Trends Report has nothing to do with adequacy. The intention is to show how much or little we know about trends. For a decision-maker, a statistically significant negative trend in a data set of this size will provide a useful datum for determining action, as will a well-determined slope bound close to zero. And knowing that we know very little about a species or sediment stratum and that, therefore, the future is quite uncertain means that an appropriate strategy can be adopted, such as worst-case versus best-case analysis. The decision-maker can use Tables 31 and 32 of our Time Trends Report as a guide to what is known and unknown. As for the issue of combining versus splitting, we have reviewed the issue extensively in this document.

# C BBL REPORT

***PCB Trends in Fish from the Lower Fox River and Green Bay, Wisconsin***
Prepared by BBL, January 2002
Comments by The Mountain-Whisper-Light Statistical Consulting, Seattle, Washington

## C.1 SUMMARY

We believe that the BBL report shows too much confidence in its projection of future PCB concentrations. These projections are based on the premise that if a quadratic model does not fit significantly better than a linear model, this should be interpreted as proof that the null hypothesis (linear model) is true and that therefore log of PCB concentration will continue declining at a constant rate into the far future. The confidence intervals on their projections do not incorporate the possibility that the assumption may not be true. The report does not make a distinction between a model that fits well over the range of observed data and the model, or models that may be appropriate for future projection. Particularly, forward projection assumes a constancy of environmental conditions that may not hold up in the future.

The report also overemphasizes statistically significant slopes in their time trends model, whereas the collection of all slopes is important to consider. The non-statistically significant slopes have lower rates of decline, and consideration of all the slopes together is an approach that gives a more balanced picture.

There are errors in the report's statistical methods, and omissions or lack of clarity in the descriptions of the methods. For example, the report did not discuss how data below detection limit were handled, though their data set, like ours, must have incorporated these data. Furthermore, the equation of percentiles for the distribution is incorrect.

We are also surprised that this document does not include more mention of or comparison to our Time Trends Report. Our Time Trends Report was released in March 2001, and this report is dated January 2002, so it seems there was ample time to make some comparisons.

We appreciate the opportunity to comment on the BBL report, as we appreciated receiving Dr. Switzer's comments. We encourage as much discussion as possible, and we presume that the Fox River Group, which retained Dr. Switzer and BBL for review and analysis, respectively, will ask Dr. Switzer to review the BBL report and make his opinions known, if they are not already about to be released. We would expect Dr. Switzer to have many of the same criticisms for the BBL report that he had for our Time Trends Report, for example:

- Splitting by reach and species is inappropriate;
- Autocorrelation could be a problem;
- The quadratic model is a model of convenience; and
- Discarding data prior to 1980 is arbitrary.

A comparison of our Time Trends Report and the BBL report will be helpful. The two reports used similar methods that differed in a few important details. For estimating the rate of decline of PCB concentration in fish near the end of the time series, the results are quite similar, with only four exceptions. These exceptions were two cases in which BBL found continuing decline with no evidence of non-linearity, while The Mountain-Whisper-Light found evidence of a late breakpoint with no decline thereafter; one case in which The Mountain-Whisper-Light found a much steeper rate of decline than did BBL, and one case in which The Mountain-Whisper-Light found evidence of an increasing trend (with no breakpoint), while BBL found no evidence of either a decline or an increase. We conclude that in the first two cases The Mountain-Whisper-Light's results are most likely correct, with the difference due to the failure of BBL to account for a seasonal effect. However, in the latter two cases the BBL results may be correct because the spread over time is too sparse to adequately estimate all the time parameters in The Mountain-Whisper-Light approach. In any case, projecting into the future requires great care. Rather than assuming a linear model is correct in the absence of evidence to the contrary, a better approach would be to fit several models that are scientifically plausible and consistent with the data, then compare the results, as we did for an example in Section B.3.2c.

Below we discuss the similarities and differences in the methods of the two reports.

## C.2 DETAILS OF MODEL FITTING

Both the BBL and The Mountain-Whisper-Light reports use a regression model to fit the log of PCB concentration. Both models assume that the residuals are normally distributed. The Mountain-Whisper-Light uses maximum likelihood to fit models and treats values below detection limit as censored observations. (See Section 2.2 of our Time Trends Report for a description of the maximum likelihood method.) The BBL report uses least squares to fit models (equivalent to the maximum likelihood method if no censoring is present) but does not specify how values below detection limit are handled. (See Section 3.3 of the BBL report for a description of their model-fitting methods.) While BBL needs to indicate how they handled BDL data, the two methods would usually give similar results when the censored proportion is small.

## C.3 LINEARITY VERSUS NON-LINEARITY

Both the BBL and The Mountain-Whisper-Light reports start with a linear model for log of PCB concentration (i.e., exponential decay of PCB concentration on the original scale), and then test for non-linearity. BBL uses a quadratic term to test for non-linearity, while The Mountain-Whisper-Light uses a breakpoint model. The Mountain-Whisper-Light also fits a quadratic model to the post-breakpoint period to test for non-linearity during the later period. The BBL quadratic model adds one parameter to the linear model, while the breakpoint model adds two parameters, the location of the breakpoint and the change in slope. In general, the one-degree of freedom test for the quadratic model should have more power than the two-degree of freedom test for the breakpoint model, but which approach has more power depends on the true shape of the trend over time and the time span considered. We chose the breakpoint model because an examination of the data indicated a change in the trends over time.

Both approaches are reasonable for fitting a model to describe a historical data set and to test for evidence of non-linearity. However, it should be kept in mind that these small data sets have poor power for detecting non-linearity. Thus, failure to find significant non-linearity does not justify confidence that the rate of decline is, in fact, constant and will continue as such into the future.

## C.4 SEPARATE VERSUS COMBINED ANALYSES

In both the BBL and The Mountain-Whisper-Light reports, separate analyses are carried out for each reach/species/sample type combination. The BBL report presents the argument for this approach on page 3-2: "Further, although grouping data across tissue types, species, or location may have appeal as a means of increasing the amount of data for assessing general trends, assessing separate trends for each category may be more informative and avoids combining species with separate life histories and relevant contaminant exposure routes." We support this view. However, a consequence of doing separate analyses is that the power for detecting deviations from linearity may be low, relative to an analysis that somehow combined data from different sample types, species, or reaches. Dr. Paul Switzer, in a critique of our Time Trends Report, criticizes the strategy of separate analyses and proposes a combined analysis. We addressed the problems with combining earlier in this review (Section B.3.2a), and chose a non-combined approach because combining may mask important trend differences among the combined groups.

## C.5 COVARIATES CONTROLLED FOR IN THE REGRESSION ANALYSIS

The BBL model controls for percent lipid and length, while The Mountain-Whisper-Light model controls for log of percent lipid and seasonality (only quite incomplete length data were available at the time of our analysis). The BBL analyses show a statistically significant effect of length in eight of fourteen analyses (excluding Green Bay zones 3 and 4). The Mountain-Whisper-Light analyses show a statistically significant seasonal effect in 12 of the 19 data sets. Since both of these variables appear to be related to PCB concentration, failing to account for one or the other may lead to inappropriate conclusions.

## C.6 RANGE OF DATA INCLUDED IN ANALYSIS

The BBL report excludes data prior to 1980 and adds some more recent data that were not available for the Time Trends Report. The BBL analysis excluded data prior to 1980 for two reasons. First, BBL states that discharges of PCBs ended in the late 1970s. If that is so, then prior to that time these discharges had been a source of PCBs in the water and were being added to the sediments. After the discharges ended, changes in PCB concentrations would be driven by dynamics of PCBs already in the sediments. The second reason supplied by BBL for dropping pre-1980 data was that analyses by others had shown a sharp decline in PCB concentrations in fish in the late 1970s, and a less steep decline in the 1980s and 1990s. (This change in rate of decline prompted the use of the breakpoint model in The Mountain-Whisper-Light analysis.) Discarding data prior to 1980 should be similar to fitting a breakpoint model with a breakpoint assumed to be at or close to 1980. If breakpoints occurred only at 1980 or earlier, then using data only after 1980 would be quite reasonable. That choice certainly would be more reasonable than the approach of some earlier analyses that fit a linear model to the entire span of time without considering a test for non-linearity. However, we found that of seven analyses with breakpoints (analyses that could be compared with BBL results), four of the seven had an earliest likely breakpoint after 1980 (Table 3). Thus, there may have been changes in slope even during the post-1980 period.

## C.7 COMPARISON OF RESULTS

Table 3 compares the analysis results from the two reports. For each report, the percent change per year is shown, along with the sample size and a *p*-value for testing whether the slope is significantly different from zero. For The Mountain-Whisper-Light analysis, this represents the post-breakpoint slope in those cases where the breakpoint model fit significantly better than the linear model.

The most striking thing about the table is the similarity of results for most data sets. Either the Time Trends Report accepted the linear model as the best fitting model, or the estimated breakpoint was early (close to 1980) so that the post-breakpoint slope and the post-1980 slope are similar. We now discuss the few cases where the results differ. And we note that the two reports differ substantially in their conclusions about changing slopes. The reports also differ about confidence and cautions concerning future projections.

## C.8 LITTLE LAKE BUTTE DES MORTS, CARP, WHOLE BODY

The BBL results show PCB levels declining over the period 1980 to 1999 at a rate of 11.8 percent per year, with no evidence of non-linearity. The Mountain-Whisper-Light analysis shows a decline until 1987, then flat (no decline) thereafter. The BBL analysis did not include length, which was not available for a large fraction of the samples. Seasonality is statistically significant ($p$ = 0.0025) in The Mountain-Whisper-Light analysis, indicating that including seasonality in the model is important. The seasonal effect is quite strong, with a maximum on July 1 and estimated PCB concentration 60 percent lower than this maximum on both October 1 and April 1. In addition, the season in which samples were taken was not constant over time, with most of the samples taken during the late summer before 1987 and most taken in the early summer and spring after 1987. Thus, ignoring seasonality would lead to a slope that is too negative.

An additional interesting observation is that seasonality was not quite significant in The Mountain-Whisper-Light analysis that fit a linear model to these data; it becomes much more significant when the breakpoint is added. We offer two possible explanations: (1) The Mountain-Whisper-Light breakpoint results are an unstable artifact, the result of fitting too many time parameters to a small data set; thus, the BBL linear model with no seasonal effect is the correct model; or (2) The Mountain-Whisper-Light breakpoint model with seasonality is correct, and the power lost due to discarding pre-1980 data and failing to include seasonality in the BBL analysis masked the true decrease in rate of decline. We believe (2) is more likely correct. While The Mountain-Whisper-Light breakpoint model has six time parameters (slope, intercept, breakpoint location, change in slope, two seasonality parameters), data are available at 15 distinct time points from 12 years. In addition, highly significant seasonal effects with a maximum in late June are also present for carp, whole body, in the two other reaches in which data are available (De Pere to Green Bay and in Green Bay Zone 2).

## C.9 LITTLE LAKE BUTTE DES MORTS, WALLEYE, SKIN-ON FILLET

The BBL results show PCB levels declining over the period 1980 to 1999 at a rate of 8 percent per year, with no evidence of non-linearity. The Mountain-Whisper-Light analysis shows a decline until 1990, then an increase at 3.4 percent per year thereafter, though this increase is not significantly different from zero. Length was not significant in the BBL analysis. The Mountain-Whisper-Light analysis found a significant seasonal effect ($p = 0.027$) with the maximum in mid-November. Data are from 20 distinct time points from 16 years, so the estimated seasonal effect is likely real. Highly significant seasonal effects are also seen in walleye, skin-on fillet in Appleton to Little Rapids and De Pere to Green Bay, though with somewhat earlier maximum times (August and September). Again, failure to account for the seasonal effect may have led to the failure of the BBL analysis to find evidence of a change in the rate of decrease.

## C.10 GREEN BAY ZONE 2, CARP, WHOLE BODY

The BBL and the Mountain-Whisper-Light reports both show a significant decline in PCB levels, but the rate of decline is much higher in the Mountain-Whisper-Light results. The Mountain-Whisper-Light analysis shows a short period in the early 1980s in which PCB levels increased, followed by a longer period of sharp decline. This early increase may not be believable. Data are from only 5 years, so that the four time parameters over years are not estimated with stability. However, one year has a large amount of data spread over the seasons so that the seasonal effect should be well estimated. The seasonal effect is significant ($p < 0.0001$). Including season in a model with no breakpoint gives an estimated rate of decline of 9.1 percent per year, comparable to the 7.7 percent per year from the BBL report.

## C.11 GREEN BAY ZONE 2, GIZZARD SHAD, WHOLE BODY

The BBL results show nearly flat PCB levels with a barely positive increase over the relatively short data series from 1989 to 1998. The Mountain-Whisper-Light results show a statistically significant increase of 5.9 percent per year. Length is not included in the BBL analysis. In the Mountain-Whisper-Light analysis there is a significant ($p = 0.030$) seasonal effect with maximum in mid-February. The Mountain-Whisper-Light results could reflect evidence of a true increase in PCB concentration over this period. However, these data are from only eight distinct time points, from 6 years. Thus, the four estimated time parameters (slope, intercept, two seasonal parameters) are not estimated as well as in the first two examples.

## TABLE 3 COMPARISON OF TIME TRENDS BETWEEN ANALYSES OF BBL AND THE MOUNTAIN-WHISPER-LIGHT

| Species | Sample Type | BBL Sample Size | TMWL Sample Size | TMWL Breakpoint Year | TMWL Earliest Breakpoint | TMWL Latest Breakpoint | 1980 Between Earliest and Latest? | TMWL % Change per Year* | TMWL *p*-Value (% = 0) | BBL % Change per Year | BBL *p*-Value (% = 0) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Little Lake Butte des Morts*** | | | | | | | | | | | | |
| Carp | skin-on fillet | 68 | 55 | 1979 | 1979 | 1985 | Yes | -6.15 | 0.0177 | -6 | <0.001 | Similar – early breakpoint |
| | whole body | 28 | 40 | 1987 | 1985 | 1990 | No | 0.71 | 0.9172 | -11.8 | <0.001 | Different, because late breakpoint |
| Northern Pike | skin-on fillet | 15 | 19 | none | | | | -11.83 | 0.0003 | -10.3 | <0.001 | Similar |
| Walleye | skin-on fillet | 63 | 63 | 1990 | 1979 | 1994 | Yes | 3.44 | 0.5576 | -8 | <0.001 | Different, because late breakpoint |
| | whole body | 18 | 18 | 1987 | 1984 | 1990 | No | 21.47 | 0.0874 | — | — | |
| Yellow Perch | skin-on fillet | 28 | 34 | 1981 | 1979 | 1996 | Yes | 0.73 | 0.8025 | -2.8 | 0.22 | Similar – early breakpoint |
| ***Appleton to Little Rapids*** | | | | | | | | | | | | |
| Carp | skin-on fillet | 25 | — | — | | | | — | — | -12.2 | <0.001 | |
| Walleye | skin-on fillet | 33 | 30 | none | | | | -9.97 | 0.0028 | -11.2 | <0.001 | Similar |
| ***De Pere to Green Bay*** | | | | | | | | | | | | |
| Carp | whole body | 97 | 90 | 1995 | 1990 | 1996 | No | 21.76 | 0.0277 | -4.6 | <0.001 | BBL found significant quadratic, so linear not correct |
| Gizzard Shad | whole body | 18 | 19 | none | | | | -5.07 | 0.0002 | — | — | |
| Northern Pike | skin-on fillet | 39 | 40 | none | | | | -9.95 | <0.0001 | -7.9 | <0.001 | Similar |
| Walleye | skin-on fillet | 116 | 120 | none | | | | -7.19 | <0.0001 | -7.7 | <0.001 | Similar |
| | whole body | 57 | 58 | none | | | | -8.11 | <0.0001 | -7.4 | <0.001 | Similar |
| White Bass | skin-on fillet | 51 | 58 | none | | | | -4.72 | 0.002 | -8.3 | <0.001 | BBL somewhat greater decline rate |
| White Sucker | skin-on fillet | 29 | 44 | none | | | | -7.9 | <0.0001 | -7.8 | <0.001 | Similar |

## TABLE 3 COMPARISON OF TIME TRENDS BETWEEN ANALYSES OF BBL AND THE MOUNTAIN-WHISPER-LIGHT

| Species | Sample Type | BBL Sample Size | TMWL Sample Size | TMWL Breakpoint Year | TMWL Earliest Breakpoint | TMWL Latest Breakpoint | 1980 Between Earliest and Latest? | TMWL % Change per Year* | TMWL *p*-Value (% = 0) | BBL % Change per Year | BBL *p*-Value (% = 0) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Green Bay Zone 2*** | | | | | | | | | | | | |
| Alewife | whole body | 43 | 44 | none | | | | -3.96 | 0.0497 | -5 | 0.04 | Similar |
| Carp | skin-on fillet | 29 | 28 | none | | | | -5.06 | 0.1557 | -8.3 | <0.001 | BBL somewhat greater decline rate |
| | whole body | 64 | 57 | 1983 | 1983 | 1984 | No | -15.54 | <0.0001 | -7.8 | <0.001 | TMWL greater decline, early breakpoint |
| Gizzard Shad | whole body | 36 | 32 | none | | | | 5.91 | 0.0144 | 1.5 | 0.45 | TMWL shows significant increase – short time series |
| Yellow Perch | skin-on fillet | 18 | 19 | none | | | | -10.75 | 0.0038 | -7.6 | <0.001 | TMWL somewhat greater decline rate |

**Notes:**
* Post-breakpoint, if there is a breakpoint.
TMWL – The Mountain-Whisper-Light Statistical Consulting

## C.12 PREDICTING FUTURE PCB CONCENTRATIONS IN FISH

Both the BBL and The Mountain-Whisper-Light reports predict future PCB concentrations based on extrapolating a constant rate of decrease in PCBs. However, if the rate of decline has been fairly constant up to 1999 but is destined to slow down (or speeding up) in the future, there is no way to test for that using these historical data. Projecting into the future requires more thought as to which models for future trends of PCBs are scientifically plausible. For future projections, the principle of using the simplest model unless there is evidence to the contrary is not necessarily the best approach. The question to ask is not whether a proposed model fits the existing historical data with greater statistical significance than the linear model, but rather which proposed models are consistent with the data and scientifically plausible. A sensitivity analysis that compares the projections based on different models would be a useful exercise. The BBL report discusses, on pages 2-9 to 2-11, several alternative models that could be considered for this exercise. We presented results earlier in this review, in Tables 2A and 2B and Figures 1 through 4, that showed very different future projections for diverse models fit to the same set of observed data.

## C.13 BACKGROUND LEVELS

An interesting point raised in the BBL report (page 4-15) is the evidence that PCBs are present in the environment generally, from sources other than the discharges into the Fox River. The report points out that, if this is true, PCB levels will not asymptote to zero but rather to some background level. An important task could be quantifying this background level to separate it out from the PCB levels due to contaminated sediments in the Fox River.

## C.14 SPECIFIC COMMENTS: BBL REPORT

### C.14.1 BBL Section 2.2 Statistical Methods for Fish Tissue Time Trend Analysis

***Page 2-5:***

The equation for exponential decay of PCB concentration, as presented, assumes that the concentration will decay to an asymptote of zero, that is, zero concentration, after some time point. This is a strong assumption, and the reader would like to see some justification for a zero asymptote rather than an asymptote of some positive value. Alternatively, the authors may wish to indicate that decay is nearly exponential during the period of data collection, but a non-zero asymptote may become important later on.

***Page 2-7, Discussion Following Equation at Top of Page:***

The authors make a strong assumption of a first-order trend in fish concentration (in the logarithmic domain). The time period of the studies (1980 and later) is probably too short to detect nonlinear trends that may be important later on. Not finding a significant quadratic term in fitting a model is not strong evidence against a quadratic term, unless the standard error is very small and the estimate is close to zero.

***Page 2-9, Changing Rates of Decline, Last Paragraph:***

The authors note that changing rates of decline could be expected due to changes in point source discharges of PCBs. There is no discussion of the role of scouring and burial of deposits, and whether these processes should lead to a constant rate of decline or a changing rate of decline.

***Page 2-11, Last Paragraph Before Section 2.3:***

The discussion (in support of fitting a simple rather than a complex model) is relevant for fitting a model to an existing data set. However, the process does not guarantee that the model is correct for long-term projection. As we noted in our discussion in other parts of our Time Trends Report (Section B.3.2c), alternative models may fit a data set equally well for the period of data collection, but have entirely different implications for future projection. In short, simplicity is a good rule in fitting a model to a data set over the range of data of interest, but does not guarantee a correct model nor the model appropriate for projection outside that range. This consideration is probably one of the most important at issue in the Fox River data analysis.

### C.14.2 BBL Section 2.4 – Trend Analysis Approach Used in This Evaluation

***Page 2-13:***

The BBL authors' discussion incorrectly dismisses the breakpoint model. The authors limited their data to the 1980–1999 period and state that they prefer their relatively simple first-order model to a "more complex alternative" such as the breakpoint model. They affirm that gaps in the data and sparse data significantly limit the ability to identify real breakpoints. We note that in our time trends analysis we identified the presence of breakpoints, an important feature of the data. Thus, limiting the data to one unchanging slope may be unrealistic. Indeed, it is difficult to specify the exact location of a breakpoint, but the presence of a breakpoint is a very important discovery about these data. Limiting the data to 1980 and later has less power to detect change.

***Page 2-13, Last Paragraph Beginning "Also, the current…":***

"Changes in surface sediment PCB concentrations over time through naturally occurring processes such as sediment deposition and mixing should lead to changes in fish tissue PCB concentrations that may be approximated using the first order decay model." This statement needs more justification.

### C.14.3 BBL Section 3.2 – Selection of Data Sets for Trend Evaluation

***Page 3-3, Third Bullet from the Top:***

Concerning elimination of data sets due to large time gaps, consider the following. Even if the time gap is substantial between two sets of points, there is no problem in fitting an exponential decay model if the numbers of points are adequate at each end of the gap. This is certainly true if the authors are going to assume linearity. In addition, the last bullet on the page indicates that the 75 percent gap criterion for data selection was chosen to avoid fitting a time trend model to essentially two separate data clusters. A 75 percent gap could certainly indicate data sets that are two clusters, with little power to detect a quadratic trend.

Given selection of the first-order model method, we feel there is no harm in fitting it to data sets of an adequate size, even with substantial gaps. If a model other than simple exponential decay has been selected, the gaps obviously could create a serious problem for testing non-linearity.

### C.14.4 Section 3.4 – Selection of Data Sets for Trend Evaluation

***Page 3-3:***

There is no discussion about how data below the detection limits were included in the analysis and no indication of the number or fraction of samples below the detection limits. The data below the detection limits are an important component of the analysis of this data set and create special problems.

### C.14.5 BBL Section 3.4 – Trend Projections

***Page 3-5, Top Paragraph:***

This paragraph includes an important statement: "The assumption that the observed rates of decline will continue is reasonable as long as the underlying ecosystem processes remain relatively unchanged." There is no argument given for why unchanging ecosystem processes necessarily imply an unchanging rate of change in PCB concentrations in fish. There is no justification for such a blanket statement. The statement may be true in the context of a particular model for how hydrologic, chemical, and biological processes interact to cause a decline in PCB concentrations in fish. Such a model needs to be presented and justified in order to make such a statement. It is quite possible that plausible models could be conjectured for which this statement is <u>not</u> true. In addition, there should be some discussion of what it means for the "underlying ecosystem processes [to] remain relatively unchanged." For example, if a flood occurred which exposed buried sediment, would that be a change in the "underlying ecosystem process?" If so, then what is the probability of such an event happening? That is, how likely is it that the "underlying ecosystem process" will in fact change in the next 10 to 20 years?

***Page 3-5, Text Two Lines Below the Equation:***

The phrase "variance-covariance matrix of the data set" should read "variance-covariance matrix of the regression coefficients."

***Page 3-6, Top:***

When ***y*** has a lognormal distribution, the expression for the mean of ***y*** and the median of ***y*** are correct, but the equation supplied for the percentiles is incorrect. The percentiles of the lognormal distribution are related to those of the underlying normal distribution of the log of ***y*** and are obtained simply by exponentiation. In addition, although the first two equations are correct on this page, their description in the sentence (second paragraph) beginning "in order to provide adjusted estimates…" is unclear and incorrect, and if this is the procedure that was used, the results are incorrect.

### C.14.6 BBL Section 4.2 – Selected Data Sets

***Page 4-2, Table at the Bottom:***

There is no explanation of how below detection limit data are handled.

***Page 4-5, Discussion About $R^2$:***

The $R^2$ is not a good measure of the precision of the time trends. It is better to look at the standard error of the coefficient of the time term in the model. The $R^2$ value can be zero and representation of the data can still be extremely accurate if, for example, the slope is zero and the standard error of the slope is very small. Again, even if using the $R^2$ measure, an $R^2$ of 0.31 would not be a particularly tight-fitting model.

Related to the goodness of fit, Figure 5E, lower left, "lake white fish, skin-on fillet, Green Bay, zone 4," appears to have an outlier. Did the authors detect it as an outlier and did they do anything about it? Given the relatively large size of this data set, it may have had little influence.

## C.14.7 BBL Section 4.3 – Regression Results

***Page 4-7, Last Sentence on the Page:***

The authors note that "equations which include a quadratic term were not used for projections because such models predict either infinitely increasing (positive quadratic term) or decreasing (negative quadratic term) PCB concentrations, neither of which is a reasonable assumption." The approach taken in the BBL report is this: test the null hypothesis that the rate of decrease in constant (i.e., linear decrease on the log scale). If the null hypothesis is not rejected, then base projections on the assumption of linear decrease. In other words, failure to reject the null hypothesis is interpreted as proof that the null hypothesis is true. As any statistician should know, this interpretation is incorrect. As discussed in Sections B.3.1, B.3.2b, and B.3.2c, a more appropriate approach to data analysis when the goal is future projection is to identify which models are compatible with the data, rather than to identify the single simplest model which is compatible with the model.

In the current situation, a quadratic term is used to test for curvature. The usual hypothesis test asks "Is there sufficient evidence in the data that a curved model fits better than a linear model?" We believe that a more appropriate question to answer is "Are the data consistent with a fairly large positive curvature?" If the answer to this later question is affirmative, then using a linear model to project into the future is highly questionable.

We used the numbers in the table on pages 4-8 to 4-9 of the BBL report to address this question of the data being consistent with curvature. In a simple quadratic model, log of PCB concentration varies as:

$$\log(PCB) = b_0 + b_1 * time + b_2 * time^2 = b_0 + (b_1 + b_2 * time) * time$$

Thus under this model, the rate of decrease in log(PCB) will change by 10 * $b_2$ over a 10-year period. In order to describe what amount of curvature is compatible with the data, we first computed the upper bound of the 90 percent confidence interval for $b_2$, computed as the estimated coefficient $b_2$ plus 1.64 times the standard error of this coefficient. This upper bound is then multiplied by 10 to get the amount by which the slope could change over a 10-year period.

The results are as follows: in 18 out of the 23 series analyzed by BBL, the data are consistent with the curvature being as big as 0.05, and in 11 of the 23 series the data are consistent with the curvature being as big as 0.15. A curvature of 0.05 means that every 10 years the slope would become bigger by 0.05. That is, the slope could change from -0.10 to -0.05 in 10 years, and change from -0.10 to 0 in 20 years. Keep in mind that the linear term in the quadratic model gives the slope at the center of the year distribution (i.e., approximately 1990). In conclusion, the BBL analysis results support the contention that most of the series are compatible with a fairly large curvature and a slope that changes substantially.

Also, the authors quoted statement is half correct in that an infinitely *decreasing* logarithm of concentration is plausible, for it would simply imply a decrease of true concentrations to zero over time.

***Page 4-10, Last Paragraph Before Section 4.3.3:***

The authors state that, "…no event or environmental condition is known that would account for a systematic shift in the rate of decline during the past 20 years." The authors should document what kind of a search they carried out through current and historical records and modeling efforts before coming to this conclusion. Is this statement "no change" supported by the sediment chemist? Is it possible that some of the PCBs are more or less bound to the sediment particulate, and that the less bound PCBs are removed at a faster rate, leaving the more bound PCBs to be removed at a lower rate?

**RETEC Comment:** Loss of the low molecular weight PCB congeners due to desorption-induced weathering is a conclusion reached by one of BBL's scientists in his doctoral dissertation for the University of Wisconsin (McLaughlin, 1994). That dissertation documented that differences in congener patterns were evident in the Fox River sediment deposits, which were attributed to natural weathering processes.

In considering events or conditions that could cause a shift in the rates of decline, if we looked at the past 50 to 100 years, is it possible that floods, droughts, and other events could intervene in this River system to produce changing rates? While the dams on the Fox River may have limited the role of unexpected events in the time course of PCB deposition and removal, is this River completely free of the unexpected?

## C.14.8 BBL Section 4.3 – Regression Results

***Pages 4-11 and 4-12, Preceding Section 4.4:***

The discussion is focused on statistically significant slopes. The discussion should be more thorough and discuss all the slopes, not only the statistically significant ones for a balanced picture.

***Page 4-12, Paragraph Beginning "Because the first order model…":***

The authors note that the fish tissue PCB concentrations were only projected using species/type/reach combinations with significant first-order trend models. There is no reason not to project other trends, which is merely a mathematical exercise. The selection of the significant first-order trend models, most of which have negative slopes, means that the projected future concentrations have been selected for cases where they are decreasing. Other models lacking significant trends clearly allow the possibility of no decrease or even an increase. Later in the paragraph, the authors note that they did not make forward projections for DPGB carp WF because the first-order model showed an inadequate fit and a quadratic model is needed. We agree that an unlimited increase in PCB concentrations in the future (from the quadratic model) is nonsensical. However, a future increase, even very far into the future, is not nonsensical. The lack of a simple model and the difficulty of getting a realistic model for forward projection is no reason to assume that increases will not occur in the future for this species.

***Page 4-12, Paragraph Beginning "Due to particular interest…":***

This paragraph begins three pages of forward projections based on the models presented earlier. Again, the projections are only as good as the assumptions, and the assumptions are only assumptions.

**RETEC Comment:** Based on historical observation, the future is quite unpredictable. Assuming that change will not occur for forward projections ignores a very fundamental and real change that is occurring now on the Fox River; the loss of Lake Michigan elevation leading to increased erosional events, as noted above by the FRG's consultant. Given that there is an immediate and expected decrease in lake elevations up to 5 feet (EPA, 2000) through the rest of this century, due to changing global climate conditions, negates any future projections based on current conditions. Other changes that could occur on the Fox River include those related to potential dam removal or failure, changes in population and use patterns, and changes in sediment load contributions from both point and non-point sources over the next 100 years.

***Page 4-15:***

The authors note on this page that "there is an influence of background PCB loading from the atmosphere or other watershed sources." Some of these background levels, such as those noted in the table on page 4-15, are substantial. The units in the table are given as micrograms per gram (ppm) and range from very low values up to rather large values such as 0.15, indicating 152 ppb or 0.15 ppm. If this kind of background level is present in the Fox River, then we would expect that a simple exponential decay would not be a valid model, but there may be a need for a model with exponential decay plus a constant term as the asymptote.

### C.14.9 BBL Section 5 – Summary and Conclusions

***Page 5-1, First Paragraph:***

"Significant declines were adequately described by first-order exponential decline in 19 of the 20 cases." Again, we emphasize that this is a model-fitting exercise that produces a valid fit for the period considered, 1980–1999. Later in the paragraph, the authors note that the first-order model (simple exponential decay, or linear or on the log scale) is the "most important representation of PCB declines in these cases…." Again, we must emphasize that representation of an existing data set by a model is a model-fitting exercise, and projections from that model (such as for later times) is a mathematical exercise whose validity depends on strong assumptions. The uncertainty in those assumptions has not been introduced into the model in any explicit form. The uncertainty in forward projections rising from uncertainty in the assumptions must be considered, but can only be considered in an informal manner in this situation.

***Page 5-2, First Full Paragraph Beginning "Assuming that…":***

The assumption that the underlying mechanisms responsible for PCB concentration declines observed since 1980 will remain largely in place is a very strong one. Clearly, if this assumption is true, and assuming that the trends continue, then forward projection is merely a mathematical exercise. Uncertainty in the assumptions is a key part of this analysis. We believe that finding changing slopes in our analysis indicates a changing River.

**RETEC Comment:** As noted above, evidence submitted by the FRG's consultants points to changes in the erosional/depositional conditions on the Fox River due to changes in lake levels. While we are confident that lake levels are dropping, and will continue to drop for the foreseeable future, any uncertainty revolves around the rate of change, and hence the rate of erosion.

***Page 5-2, Last Paragraph Beginning "In conclusion…" to the End of the Page:***

A simple model does not imply that it is the correct model, nor that alternative models may not fit as well. In other parts of this document (Section B.3.2c), we give examples of alternative models that fit equally well over the range of observed data but have drastically different forward projections. We note that the forward projection to the year 2020 is 20 years beyond the end of the 20-year period of data used for fitting the models. We question the ability to aim accurately 20 years ahead given the wobbly-ness of the "barrel" (uncertainty in the fitted curves and uncertainty in assumptions). The role of assumptions is critical here. They are dealt with rather briefly in the BBL report, and either these authors or other scientists need to carefully consider issues of the stability of the River over time. Viewing a very long history of the River (many decades) may be helpful.

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Principal Data Analyst, Lawrence Radiation Laboratory, Berkeley, CA, 1961–66
Demographic Intern, The Population Council, New York City, 1967
Statistical Consultant, New Jersey Neuro-Psychiatric Institute, 1967–1968
Computer Clinic Consultant, Princeton University Computer Center, 1967–1968
Research Assistant, Statistics Department, Princeton University, 1968
Field Associate, Thailand and Indonesia, The Population Council, 1969–1971
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Assistant Professor, Department of Biostatistics, University of Washington, 1974–1982
Associate Professor, Department of Biostatistics, University of Washington, 1982–1989
Affiliate Assoc. Professor, Dept. of Biostatistics, University of Washington, 1989–present
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Owner, The Mountain-Whisper-Light Statistical Consulting, 1989–present

**Other Appointments:**

Consultant, NIH Study Section on Human Infertility, 1978
Consultant, Ford Foundation, Djakarta, Indonesia, 1971
Associate, Center for Studies in Demography and Ecology, University of Washington, 1976
Affiliate, Center for Health Services Research, University of Washington, 1977
Consultant, Science Advisory Board, EPA, 1985
Member, Hanford Health Effects Panel, 1986
Consultant, SBIR Review Panel, 1987
Consultant, World Bank, 1988

**Honors:**

Distinguished Honorary Citizenship, Washington State, 1983
Co-recipient: Licht Award from the American College of Rehabilitation Medicine for excellence in Scientific Writing, 1993
Co-recipient: Best Research Paper award (physiatrist category) from the Phys. Med. and Rehabilitation Research Foundation and American Association of Phys. Med. and Rehabilitation, 1995

**Membership in Professional Organizations:**

American Statistical Association
Biometric Society

**Consulting**

***Examples:***

Design and analysis of drug and treatment trials
Malpractice -- effects of cancer treatment delay
Accuracy of pap smears
Effectiveness of rehabilitation services
Evaluation of lens implants
Asbestos risk assessment
Racial discrimination -- develop and analyze database
Survival analysis
Neurobehavioral outcomes following head injury

***Research (Principal Investigator of $2.5 million in grants and contracts):***

Cancer risk from asbestos in drinking water
Pathways of community exposure to arsenic from a smelter
Cancer risk from phenoxy herbicides
Hospice use and cost in Western Washington
Adult respiratory distress syndrome -- epidemiology and survival
Treatment and referral patterns for cervical cancer
Auto exhaust and cancer

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133 Mulroy MF, Salinas FV, Larkin KL, Polissar NL: Ambulatory surgery patients may be discharged before voiding after short-acting spinal and epidural anesthesia. In press, Anesthesiology, 2002.

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135 Cai JM, Ferguson MS, Polissar N, Hatsukami TS, Yuan C: Classification of human carotid atherosclerotic lesions using in vivo multi-contrast MR imaging. In press, Circulation.

# CURRICULUM VITAE

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**Education:**

University of Washington, BS, Mathematics, 1975
University of Michigan, MS, Computer Science, 1976
Harvard University, PhD, Applied Mathematics, 1982
Harvard School of Public Health, Post-Doc, Biostatistics, 1982–84

**Professional Positions:**

Research Assistant and Computer Programmer, Kaiser Services Research Center, Portland, OR, 1975
Computer Programmer/Data Base Engineer, Urban Systems Research and Engineering, Cambridge, MA, 1976–77
Teaching Fellow, Applied Mathematics, Statistics, Harvard University, 1980–81
Post-doctoral Research Fellow, Department of Biostatistics, Harvard School of Public Health and Dana-Farber Cancer Institute, Boston, MA, 1982–84
Assistant Professor, Department of Biostatistics, University of Washington, 1984–92
Research Methodology Consultant, School of Nursing, University of Washington, 1988–present
Research Scientist, Department of Biostatistics, University of Washington, 1992–present

**Honors:**

Phi Beta Kappa, 1976
Finalist, Post-doctoral Student Prize Competition, Society for Medical Decision Making, 1983
Association for Health Services Research Article-of-the-Year Award, 1991 (co-author with P Diehr)

## Research Support

***Active:***

R01 NR04142 (Margaret M. Heitkemper, PI) 12/1/1995–1/31/2007

NIH, National Institute of Nursing Research
Nursing Management of IBS: Improving Outcomes
The major goal of this project is to compare the effectiveness of a comprehensive self-management intervention to reducing GI symptoms and enhance quality of life in women and men with medically diagnosed IBS, and to test the effectiveness of a telephone vs. face-to-face intervention.

NRI 98-194-2 (Bonnie G. Steele, PI) 10/1/2000–09/30/2004

U.S. Department of Veterans Affairs
Promoting Activity and Exercise in Chronic Pulmonary Disease
The goals of this project are to evaluate an exercise adherence intervention to maintain high daily levels of activity and exercise, determine personal predictors of adherence, determine the intervention's effect on outcomes, and identify costs of the intervention versus standard treatment.

(Robert Pearlman, PI) 10/1/2000–09/30/2004

U.S. Department of Veterans Affairs
Center for Ethics Evaluation
The goal of this project is to develop methods and measures for the evaluation of ethics activities in the Veterans Affairs health systems.

R01 NR007787 (Mary Ersek, PI) 3/1/2002–2/28/2006

NIH, National Institute of Nursing Research
Self Management Intervention for Elders with Chronic Pain
The goal of this project is to test a pain self-management program in a group of elders residing in retirement communities.

***Completed:***

R01 NR04101 (Margaret M. Heitkemper, PI) 9/20/1995–7/31/2000

NIH, National Institute of Nursing Research
Physiological Arousal in Women with IBS
The major goals of this project are to compare women with medically diagnosed IBS and asymptomatic control women with respect to ANS balance, ANS function, and physiological arousal.

R01 NR04901 (Pamela H. Mitchell, PI) 04/01/1999–03/31/2002

NIH, National Institute of Nursing Research
Improving CPP Management: Information Feedback & Nursing
The goals of this project are to evaluate, in the context of optimal medical management of cerebrovascular dynamics, the impact of a bedside system of cerebral perfusion pressure (CPP) information feedback on nursing minute to minute management of CPP and the relationship of that management to patient functional outcome.

R55 NR04101 (Monica Jarrett, PI) 09/30/1999–09/29/2001

NIH, National Institute of Nursing Research
Physiological Arousal in IBS: Gender Differences
The goals of this project are to describe and compare IBS experiences in women and men, compare visceral hyper-sensitivity in women and men with and without IBS, and examine factors that cause or exacerbate symptoms in IBS.

CP 94-050.A (Robert A. Pearlman, PI) 06/01/1995–03/31/1998

U.S. Dept. Veterans Affairs
Development and Evaluation of an Advance Care Planning Workbook
Developed and evaluated the use of a patient-centered workbook in clinical practice to increase patient autonomy in health care decision making.

(Robert A. Pearlman, PI) 04/01/1997–06/30/1999

Evaluation of a Comprehensive Advance Care Planning Intervention
U. S. Dept. Veterans Affairs
Evaluated the effectiveness of a comprehensive advance care planning intervention in clinical practice.

(Barry Saver, PI) 05/01/1998–10/31/1999

Robert Wood Johnson Foundation
Investigation into Specialist Payment: Effects on Cost and Treatment
Studied the effects of the methods three HMOs use to pay for the services of specialist physicians on the rates of procedures performed by these specialists and cost of care.

R29 CA62477 (Diana J. Wilkie, PI) 01/01/1994–12/31/1999

NIH, National Institute of Nursing Research
Effects of a Nurse Coaching Protocol on Cancer Pain
Examined the effect of coaching 200 patients with lung cancer for 6 weeks to self-monitor and communicate their pain to clinicians in a systematic, efficient manner (COACHING).

**Research Papers in Refereed Journals:**


1 Anderson JR, Cain KC, Gelber RD: Analysis of survival by tumor response category. J Clin Oncol 1:710-19, 1983.

2 Mehta CR, Cain KC: Charts for the early stopping of pilot studies. J Clin Oncol 2:676-682, 1984.

3 Cain KC, Lange NT: Approximate case influence for the proportional hazards regression model with censored data. Biometrics 40:493-99, 1984.

4 Doubilet P, Cain KC: Superiority of sequential over simultaneous testing. Med Decis Making 5:447-451, 1986.

5 Bennet JM, Cain KC, Glick JH, Johnson G, Ezdiwli E, O'Connell MJ: The significance of bone marrow involvement in non-Hodgkin's lymphoma: The Eastern Cooperative Oncology Group (ECOG) experience. J Clin Oncol 4:1462-69, 1986.

6 Breslow NE, Cain KC: Logistic regression for two stage case-control data. Biometrika 75:11-20, 1988.

7 Cain KC, Breslow NE: Logistic regression analysis and efficient design for two-stage studies. Am J Epidemiol 128:1198-1206, 1988.

8 Uhlmann RF, Pearlman RA, Cain KC: Physicians' and spouses' predictions of elderly patients' resuscitation preferences. J Gerontol 43:M115-121, 1988.

9 Ellis S, Alderman EL, Cain K, Wright A, Bourassa M, Fisher L: Morphology of left anterior descending coronary territory lesions of a predictor of anterior myocardial infarctions: A CASS registry study. J Am Coll Cardiol 13(7):1481-1491, 1989.

10 Uhlmann RF, Pearlman RA, Cain KC: Understanding of elderly patients resuscitation preferences by physicians and nurses. West J Med 150:705-707, 1989.

11 Diehr P, Cain K, Connell F, Volinn E: What is too much variation? The null hypothesis in small area analysis. Health Serv Res 24(6):741-771, 1990.

12 Kahn SE, Larson VG, Beard JC, Cain KC, Fellingham GW, Schwartz RS, Veth RC, Stratton JR, Cerqueira MD, Abrass IB: Effects of exercise on insulin action, glucose tolerance and insulin secretion in aging. Am J Physiol 258:E937-943, 1990.

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14 Schwartz RS, Shuman WP, Larson V, Cain KC, Fellingham GW, Beard JC, Kahn SE, Stratton JR, Cerqueira MD, Abrass IB: The effect of intensive endurance exercise training on body fat distribution in young and older men. Metabolism 40(5):545-551, 1991.

15 Stratton JR, Chandler WL, Schwartz RS, Cerqueira MD, Levy W, Kahn SE, Larson VG, Cain KC, Beard JC, Abrass IB: Effects of physical conditioning on fibrinolytic variables and fibrinogen in young and older healthy adults. Circulation 83:1692-1697, 1991.

16 Raghu G, DePaso WJ, Cain K, Hamnar SP, Dreis DF, Hutchinson J, Pardee NE, Winterbauer RH: Azathioprine combined with prednisone in the treatment of idiopathic pulmonary fibrosis: A prospective double-blind, randomized, placebo-controlled clinical trial. Am Rev Respir Dis 144:291-296, 1991.

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18 Schwartz RS, Cain KC, Shuman WP, Larson V, Stratton JR, Beard JC, Kahn SE, Cerqueira MD, Abrass IB: Effect of intensive endurance training on lipoprotein profiles in young and older men. Metabolism 41(6):649-654, 1992.

19 Neiman RS, Cain K, Ben Arieh Y, Harrington D, Mann RB, Wolf BC: A comparison between the Rappaport classification and working formulation in cooperative group trials: the ECOG experience. Hematol-Pathol. 6(2):61-70, 1992.

20 Cain KC, Kronmal RA, Kosinski AS: Analyzing the relationship between change in a risk factor and risk of disease. Stat Med 11(6):783-97, 1992.

21 Diehr P, Cain KC, Kreuter W, Rosenkranz S: Can small-area analysis detect variation? The power of small area variation analysis. Med Care 30(6):484-502, 1992.

22 Chandler WL, Veith RC, Fellingham GW, Levy WC, Schwartz RS, Cerquiera MD, Kahn SE, Larson VG, Cain KC, Beard JC, et al.: Fibrinolytic response during exercise and epinephrine infusion in the same subjects. J Am Coll Cardiol 19(7):1412-20, 1992.

23 Kahn SE, Larson VG, Schwartz RS, Beard JC, Cain KC, Fellingham GW, Stratton JR, Cerqueira MD, Abrass IB: Exercise training delineates the importance of b-cell dysfunction to the glucose intolerance of human aging. J Clin Endocrinol Metabol 74(6):1336-42, 1992.

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27 Diehr P, Cain K, Ye Z, Abdul-Salam F: Small area variation analysis: Methods for comparing several diagnosis-related groups. Med Care 31(5):YS45-53, 1993.

28 Cain KC, Diehr P: The relationship between small-area variations in the use of health care services and inappropriate use: A commentary. Health Serv Res 28(4):411-418, 1993.

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30 Patrick DL, Starks HE, Cain KC, Uhlmann RF, Pearlman RA: Measuring preferences for health states worse than death. Med Decis Making 14(1):9-18, 1994.

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32 Murphy SA, Beaton RD, Cain K, Pike K: Gender differences in fire fighter job stressors and symptoms of stress. Women and Health 22(2):55-69, 1994.

33 Alexander EM, Wagner EH, Buchner DM, Cain KC, Larson EB: Do surgical brain lesions present an isolated dementia? A population-based study. J. Am. Geriatric Soc. 43:138-143, 1995.

34 Pearlman RA, Cole W, Patrick DL, Starks HE, Cain, KC: Advance care planning: Eliciting patient preferences for life-sustaining treatment. Patient Education and Counseling 26(1-3):353-361, 1995.

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36 Jarrett M, Cain K, Heitkemper M, Levy RL: Relationship between gastrointestinal and dysmenorrheic symptoms at menses. Res Nurs Hlth 19:45-51, 1996.

37 Heitkemper M, Jarrett M, Cain K, Shaver J, Bond E, Woods NF, Walker E: Increased urine catecholamines and cortisol in women with irritable bowel syndrome. Am J Gastroenterol 91(5):906-913, 1996.

38 Levy R, Jarrett MJ, Cain K, Heitkemper MM: The relationship between daily life stress and gastrointestinal symptoms in women with irritable bowel syndrome. J Behav Med 20(2):177-193, 1997.

39 Levine BS, Jarrett MJ, Cain KC, Heitkemper MM: Psychophysiological response to a laboratory challenge in women with and without diagnosed irritable bowel syndrome. Res Nurs Hlth 20(5):431-441, 1997.

40 Patrick DL, Pearlman RA, Starks HE, Cain KC, Cole WG, Uhlmann RF: Validation of preferences for life-sustaining treatment: Implications for advance care planning. Ann Intern Med 127:509-17, 1997.

41 Mitchell PH, Shannon SE, Cain KC, Hegyvary ST: Critical care outcomes: Linking structures, processes, and organizational and clinical outcomes. Am J Crit Care 5(5):353-63, quiz 364-5, 1997.

42 Baldwin LM, Larson EH, Connell FA, Nordlund D, Cain KC, Cawthon ML, Byrns P, Rosenblatt RA: The effect of expanding Medicaid prenatal services on birth outcomes. Am J Public Health 88(11):1623-9, 1998.

43 Jarrett M, Heitkemper MM, Cain K, Tuftin M, Walker E, Bond E, Levy R: The relationship between psychological distress and gastrointestinal symptoms in women with irritable bowel syndrome. Nurs Res 47(3):154-161, 1998.

44 Murphy SA, Johnson C, Cain KC, Das Gupta A, Dimond M, Lohan J, Baugher R: Broad-spectrum group treatment for parents bereaved by the violent deaths of their 12- to 28-year-old children: A randomized controlled trial. Death Studies 22(3):209-35, 1998.

45 Murphy SA, Gupta AD, Cain KC, Johnson LC, Lohan J, Wu L, Mekwa J: Changes in parents' mental distress after the violent death of an adolescent or young adult child: A longitudinal prospective analysis. Death Studies 23(2):129-59, 1999.

46 Murphy SA, Braun T, Tillery L, Cain KC, Johnson LC, Beaton RD: PTSD among bereaved parents following the violent deaths of their 12- to 28-year-old children: A longitudinal prospective analysis. J Trauma Stress 12(2):273-91, 1999.

47 Murphy SA, Lohan J, Braun T, Johnson LC, Cain KC, Beaton RD: Parents' health, health care utilization, and health behaviors following the violent deaths of their 12- to 28-year-old children: A prospective longitudinal analysis. Death Studies 23(7):589-616, 1999.

48 Kyes KB, Wickizer T, Franklin G, Cain K, Cheadle A, Madden C, Murphy L, Plaeger-Brockway R, Weaver M: Evaluation of the Washington state Workers' Compensation Managed Care Pilot I: Medical outcomes and patient satisfaction. Medical Care 37(10):972-81, 1999.

49 Cheadle A, Wickizer T, Franklin G, Cain K, Joesch J, Kyes K, Murphy L, Plaeger-Brockway R, Weaver M: Evaluation of the Washington state Workers' Compensation Managed Care Pilot Project II: Medical and disability costs. Medical Care 37(10):982-93, 1999.

50 Lewis LL, Shaver JF, Woods NF, Lentz MJ, Cain KC, Hertig V, Heidergott S: Bone resorption levels by age and menopausal status in 5,157 women. Menopause 7(1):42-52, 2000.

51 Jarrett M, Heitkemper M, Cain KC, Burr RL, Hertig V: Sleep disturbance influences gastrointestinal symptoms in women with irritable bowel syndrome. Dig Dis Sci 45(5):952-9, 2000.

52 Burr RL, Heitkemper M, Jarrett M, Cain KC: Comparison of autonomic nervous system indices based on abdominal pain reports in women with irritable bowel syndrome. Biol Res Nurs 2(2):97-106, 2000.

53 Huang MC, Liu CC, Chi YC, Huang CC, Cain K: Parental concerns for the child with febrile convulsion: Long-term effects of educational interventions. Acta Neurol Scand 103(5):288-93, 2001.

54 Heitkemper M, Jarrett M, Cain KC, Burr R, Levy RL, Feld A, Hertig V: Autonomic nervous system function in women with irritable bowel syndrome. Dig Dis Sci. 46(6):1276-84, 2001.

55 Pearlman RA, Starks H, Cain KC, Cole WG, Patrick DL, Uhlmann RF: Integrating preferences for life-sustaining treatments and health states ratings into meaningful advance care decisions. Verh K Ned Akad Wet, Afd Natuur, Tweed Reeks 102:39-53, 2001.

56 Huang MC, Liu CC, Chi YC, Huang CC, Cain K: Parental concerns for the child with febrile convulsion: Long-term effects of educational interventions. Acta Neurol Scand 103(5):288-93, 2001.

57 Wilkie DJ, Huang HY, Reilly N, Cain KC: Nociceptive and neuropathic pain in patients with lung cancer: A comparison of pain quality descriptors. J Pain Symptom Manage 22(5):899-910, 2001.

58 Shannon SE, Mitchell PH, Cain KC: Patients, nurses, and physicians have differing views of quality of critical care. J Nurs Scholarsh 34(2):173-9, 2002.

59 Zierler BK, Meissner MH, Cain K, Strandness DE Jr: A survey of physicians' knowledge and management of venous thromboembolism. Vasc Endovascular Surg 36(5):367-75, 2002.

# CURRICULUM VITAE

Thomas Lumley, Ph.D.
Assistant Professor, University of Washington

**Education:** Monash University, Melbourne, Australia, BS, Pure Mathematics, 1991
University of Oxford, Oxford, United Kingdom, MS, Applied Statistics, 1993
University of Washington, Seattle, Ph.D., Biostatistics, 1998

**Professional Positions:**

Research Assistant, Higher Education Advisory & Research Unit, Monash University, 1991–92
Biostatistician, NHMRC Clinical Trials Centre, University of Sydney, 1993–95
Assistant Professor, Department of Biostatistics, University of Washington, 1998–present

**Other Appointments:**

Free R Statistical System Core Development Team (http://www.r-project.org)
Orca Development Team
Omega Statistical Computing Project
XLISP-Stat Statistical Environment (contributor)

**Honors:**

Faculty of Science Faculty Scholar, Monash University, 1987–1990
Commonwealth Scholarship & Fellowship Plan award, 1992–1993
Howard Hughes Medical Institute Predoctoral Fellowship, 1995
Donovan J. Thompson Award for Academic Excellence in Biostatistics, 1996

**Research Papers in Refereed Journals:**

1. Lumley T: Coeducation and factors affecting the choice of university courses. Australian Educational Researcher 19(2):51-60, 1992.
2. Jorgensen JO, Gillies RB, Hunt DR, Caplehorn JRM, Lumley T: A Simple and effective way to reduce postoperative pain after laparoscopic cholecystectomy. Australian & New Zealand Journal of Surgery 65:466-469, 1995.
3. Lumley T: Efficient execution of Stone’s likelihood ratio tests for disease clustering. Computational Statistics and Data Analysis 20: 499-510, 1995.
4. Sullivan J, Learmont J, Lumley T, Geczy A, Cook L: A direct association between HIV and AIDS in blood transfusion donors and recipients. AIDS Research and Human Retroviruses 11:1147-1148, 1995.
5. Lumley T: Generalized estimating equations for ordinal data: A note on working correlation structures. Biometrics 52:354-361, 1996.
6. Lumley T: XLISP-Stat tools for building generalized estimating equation models. Journal of Statistical Software. 1(3):1-20, 1996.
7. Cozzi PJ, Lynch WJ, Robson N, Vontethoff T, Lumley T, Morris DL: In vitro and in vivo assessment of urethral warming catheters for transperineal cryoablation of prostate carcinoma. British Journal of Urology 78:589-595, 1996.
8. Beller E, Tattersall M, Lumley T, et al.: Improved quality of life with megestrol acetate in patients with endocrine-insensitive advanced cancer: a randomized placebo-controlled trial. Annals of Oncology 8:277-283, 1997.
9. Mackerras D, Lumley T: First- and second-year effects in trials of calcium supplementation on the loss of bone density in post-menopausal women. Bone 21; 6:527-533, 1997.
10. Cannavo M, Fairbrother G, Owen D, Lumley T: A randomized trial of calcium alginate vs sodium hydrochlorate dressing pad in the management of post-surgical abdominal wounds. Journal of Wound Care 7:57-62, 1998.
11. Caplehorn J, Lumley T, Irwig L, Saunders J: Changing attitudes and beliefs of staff working in methadone maintenance programs. Australian and New Zealand Journal of Public Health 22:505-508, 1998.
12. Lumley T: Survival analysis in XLISP-Stat: A semi-literate program. Journal of Statistical Software. 3:1-90, 1998
13. Lumley T, Heagerty PJ: Weighted empirical adaptive variance estimators for correlated data regression. Journal of the Royal Statistical Society, Series B 61:459-477, 1999
14. Veenstra D.L.,Saint S, Saha S; Lumley T, Sullivan S: Efficacy of antiseptic impregnated central venous catheters in preventing nosocomial infections: A meta-analysis. JAMA 281:261-267, 1999
15. Heagerty PJ, Lumley T: Window subsampling of estimating functions with application to regression models. Journal of the American Statistical Association 95:197-211, 2000
16. Lumley T, Heagerty PJ: Graphical Exploratory Analysis of Survival Data. Journal of Computational and Graphical Statistics 9:738-749, 2000

17 Heagerty PJ, Lumley T, Pepe MS: Time-dependent ROC curves for censored survival data and a diagnostic marker. Biometrics 56:337-344, 2000

18 Lumley T, Levy D: Bias in the case-crossover design: implications for studies of air pollution. Environmetrics 11:689:704, 2000

19 Lumley T, Sheppard L: Assessing seasonal confounding and model selection bias in air pollution epidemiology using positive and negative control analyses. Environmetrics 11:705-717, 2000

20 Jarvik JG, Robertson WD, Wessbecher F, Reger K, Solomon C, Whitten T, Deyo RA: Variation in the quality of lumbar spine magnetic resonance imaging in Washington state. Radiology 215: 483-90, 2000

21 Martin AJ, Glasziou PP, Simes RJ, Lumley T: A comparison of standard gamble, time trade-off and adjusted time trade-off scores. International Journal of Technology Assessment in Health Care 16:137-47, 2000

22 Levy D, Lumley T, Sheppard L, Kaufman J, Checkoway H: Referent selection in case-crossover analyses of acute health effects of air pollution. Epidemiology 186-92, 2001

23 Sutherland P, Rossini A, Lumley T, Lewin-Koh N, Dickerson J, Cox Z, Cook D: ORCA: A visualisation toolkit for high-dimensional data. Journal of Computational and Graphical Statistics 9: 509-529, 2000

24 Yu O, Sheppard L, Lumley T, Koenig JQ, Shapiro GG: Effects of ambient air pollution on symptoms of asthma in Seattle-area children. Environmental Health Perspectives 108:1209-1214, 2000

25 Levy D, Sheppard L, Checkoway H, Kaufman J, Lumley T, Koenig J, Koepsell T, Siscovick D: A case-crossover analysis of particulate matter air pollution and out-of-hospital primary cardiac arrest. Epidemiology 12:193-9, 2001

26 Psaty BM, Furberg CD, Kuller LH, Cushman M, Savage PJ, Levine D, O'Leary DH, Bryan N, Anderson M, Lumley T: The association between level of blood pressure and the risk of cardiovascular disease: The cardiovascular health study. Archives of Internal Medicine 161:1183-92, 2001

27 Lumley T, Kronmal D, Cushman M, Manolio TA, Goldstein S: Predicting stroke in the elderly: Validation and web-based application. Journal of Clinical Epidemiology 55(2) 129-36, 2002

28 Lumley T, Simes RJ, Gebski V, Hudson HM: Combining components of quality of life to increase precision and evaluate trade-offs. Statistics in Medicine 20:3231—3249, 2002

29 Lumley T, Sutherland P, Rossini A, Lewin-Koh N, Cook D, Cox Z: Visualising high-dimensional data in time and space: ideas from the Orca project. Chemometrics and Intelligent Laboratory Systems 60: 189-95, 2002

30 Goswami E, Larson T, Lumley T, Liu L-JS: Spatial characteristics of fine particulate matter: identifying representative monitoring locations in Seattle, Washington. Journal of the Air & Waste Management Association 52: 324-333, 2001

31 Lumley T: Network meta-analysis for indirect treatment comparisons. Statistics in Medicine 21:2313-2324, 2002

32 Lumley T, Diehr P, Emerson S, Chen L: The importance of the Normality Assumption in Large Public Health Data Sets. Annual Review of Public Health 23:151-69, 2002

33 Psaty BM, Smith NL, Heckbert SR, Vos HL, Lemaitre RN, Reiner AP, Siscovick DS, Bis J, Lumley T, Longstreth WT, Rosendaal FR: Diuretic therapy, the alpha-adducin variant, and the risk of myocardial infarction or stroke in subjects with treated hypertension. JAMA 287(13) 1680-9, 2002

34 Holt VL, Kernic MA, Lumley T, Wolf ME, Rivara FP: Civil protection orders and risk of subsequent police-reported violence. JAMA 288(5):589-94, Aug 7, 2002

# CURRICULUM VITAE

Steven Eric McKinney, Ph.D.
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**Education:** University of British Columbia, Vancouver, BC, BS, Statistics Pathway, 1981
University of Waterloo, Waterloo, ON, MM, Statistics, 1982
University of Washington, Seattle, WA, MS, Biostatistics, 1988
University of Washington, Seattle, WA, PhD, Biostatistics, 1995

**Professional Positions:**

Statistician and Software Engineer, Princess Margaret Hospital, Toronto, ON, 1982–1985
Statistical and Computing Consultant, The Research Group, Seattle, WA, 1991–1994
Statistician and Software Engineer, The Research Group, Seattle, WA, 1994–1998
Statistical Consultant, The Mountain-Whisper-Light Statistical Consulting, Seattle, WA, 1999–2000
Senior Consultant, Insightful Corporation, Seattle, WA, 2000–present

**Membership in Professional Organizations:**

American Statistical Association
American Association for the Advancement of Science

**Publicly Available Software:**

Xlisp-s: A series of routines to allow users of Xlisp or LispStat to interactively transfer data to and access functions in New S. (kilroy@biostat.washington.edu) [01/16/92, 02/29/92] Version 1.1 [02/05/93]. Website: http://www.stat.cmu.edu/xlispstat/

Autopaint: A toolkit for visualizing data in four or more dimensions. Website: ftp://enterprise.pulmcc.washington.edu/pub/Autopaint/

**Research Papers in Refereed Journals:**

1 Gerbino A, McKinney S, Glenny RW: “Correlation between ventilation and perfusion determines ventilation-perfusion heterogeneity in endotoxemia.” J. Appl. Physiol. 88:1933-1942, 2000.

2 Deem S, Hedges RG, McKinney S, Polissar NL, Alberts M, Swenson ER: “Mechanisms of improvement in pulmonary gas exchange during isovolemic hemodilution.” J Appl Physiol. 87:132-141, 1999.

3 Altemeier WA, McKinney S, Glenny RW: “Fractal nature of regional ventilation distribution.” J. Appl. Physiol. 88:1551-1557, 2000.

4 Sinclair SE, McKinney S, Glenny RW, Bernard SL, Hlastala MP: “Exercise alters fractal dimension and spatial correlation of pulmonary blood flow in the horse.” J Appl Physiol. 88:2269-2278, 2000.

5 Deem S, Hedges R, McKinney S, Polissar N, Alberts M, Swenson ER: “Improvements in pulmonary gas exchange after hemodilution occur in conjunction with changes in VA/Q, pulmonary blood flow distribution and expired nitric oxide.” J Appl Physiol. 87:132-141, 1999.

6 Deem S, Hedges R, McKinney S, Polissar N, Swenson ER: Hemodilution during venous gas embolization improves gas exchange without altering VA/Q or pulmonary blood flow distributions Anesthesiology 91:1861-1872, 1999.

7 Altemeier WA, Robertson HT, McKinney S, Glenny RW: “Pulmonary embolization caused hypoxemia by redistributing regional blood flow without changing ventilation.” J Appl Physiol. 85:2337-2343, 1998.

8 Glenny RW, Polissar NL, McKinney S, Robertson HT: “Temporal heterogeneity of regional pulmonary perfusion is spatially clustered”, J. Appl. Physiol. 79(3):986-1001, 1995.

9 Volinn E, Lai D, McKinney S, Loeser D: “When back pain becomes disabling: a regional analysis.” Pain 33:33-39, 1988.

10 Ciampi A, Hogg S, McKinney S, Thiffault J: “RECPAM: A computer program for recursive partition and amalgamation for censored survival data and other situations frequently occurring in biostatistics. I. Methods and program features.” Computer Methods and Programs in Biomedicine 26:239-256, 1988.

11 Ciampi A, Lawless J, McKinney S, Singhal K: “Regression and recursive partition strategies in the analysis of medical survival data.” J. Clin. Epidemiol. 41(8):737-748, 1988.

12 Ciampi A, Chang CH, Hogg S, McKinney S: Recursive Partition: A versatile method for exploratory data analysis in biostatistics. Joshi Festschrift Volume, I.B. McNeill and G.J. Umphrey, editors. D. Reidel Publishing Co., p. 23–50, 1987.

13 Simpson W, McKinney S, Carruthers J, Gospodarowicz M: “Papillary and follicular thyroid cancer: Prognostic factors in 1578 patients”. Am. J. Med. 83:(3):479-488, 1987.

14 Simpson W, McKinney S: “Canadian survey of thyroid cancer”. Can. Med. Assoc. J. 132(8):925-931, 1985

15 Warr D, McKinney S, Tannock I: “Influence of measurement error on assessment of response to anticancer chemotherapy: Proposal for a new criteria of tumor response”. J. Clin. Oncol. Vol2(9):1040-1046, 1984.

# CURRICULUM VITAE

Paul D. Sampson, Ph.D.
8458 – Tillicum Road S.W., Seattle, Washington 98136
(206) 685-2664/Fax (206) 324-5915
email: pds@stat.washington.edu

**Education:** Brown University, BS, Applied Mathematics, 1973
Brown University, MS, Applied Mathematics, 1974
University of Michigan, PhD, Statistics, 1979

## Professional Positions:

National Science Foundation Student-Originated Study of Pollution in Mt. Hope Bay, Rhode Island, 1972
Research Assistant, Statistical Research Laboratory, University of Michigan, 1974–1978
Research Assistant, Department of Statistics, University of Michigan, 1976
Teaching Assistant, Department of Statistics, University of Michigan, 1978–1979
General Statistical Consulting, 1978–2000
Research Associate (Assistant Professor), Department of Statistics, University of Chicago, 1979–1981
Assistant Professor, Director of Statistical Consulting Program, Department of Statistics, University of Washington, 1981–1988
Visiting Lecturer, Department of Statistics, University of British Columbia, 1985–1987
Associate Professor and Director of Statistical Consulting Program, Department of Statistics, University of Washington, 1988–1998
Faculty Member, Quantitative Ecology and Resource Management, University of Washington, 1991–1998
Visiting Scholar, Division of Applied Mathematics, Brown University, 1992
Directeur de Recherche Associé, Centre de Géostatistique, Ecole Nationale Superieure des Mines de Paris, Fontainebleau, France, 1993
Visiting Scientist, Laboratoire de Biométrie, Institut Nationale de la Recherche Agronomique, Montfavet, France, 1993
Acting Director (1998), Executive Committee, National Research Center for Statistics and the Environment, University of Washington, 1996–1998
Senior Statistician, Seattle Longitudinal Study on Alcohol and Pregnancy, University of Washington, 1984–present
Research Professor and Director of Statistical Consulting Program, Department of Statistics, University of Washington, 1998–present
Assistant Director, National Research Center for Statistics and the Environment, University of Washington, 1999–present

## Other Appointments:

Principal Organizer, Joint Biostatistics-Statistics Statistical Consulting Program
Director of Center for Statistical Consulting, University of Washington Cost Center
Assistant Director and Head of Visitor Committee, National Research Center for Statistics and the Environment
Regular Member of Committes for Ph.D. Qualifying Examinations in Applied Statistics
Graduate Student Supervision for Statistics, Biostatistics, Fisheries, and NRCSE Project Grants

**Honors and Awards:**

Brown University Graduate School Fellowship, 1973–1974
Institute of Mathematical Statistics Award, Department of Statistics, University of Michigan, 1975
University of Michigan Fellowship (pre-candidacy), 1975–1976
University of Michigan Rackham Fellowship, 1976–1977
Member, Society of the Sigma Xi, University of Chicago, 1980

**Membership in Professional Organizations:**

American Statistical Association
Biometric Society
Institute of Mathematical Statistics
International Environmetric Society

**Consulting**

***Past:***

| | |
|---|---|
| 1982 | SIMS/EPA Cooperative Agreement for Statistical Research on Problems in Water Pollution, Summer Salary 1982 |
| 1982–1983 | Nisqually Indian Tribe Contract for Development of an In-season Run Size Estimator for the Native Chum Stock in the Nisqually River (funding from the Bureau of Indian Affairs); PI (co-investigator Dr. M. L. Thompson) |
| 1984 | University of Washington Graduate School Research Fund Award for Research in Morphometrics; PI |
| 1984–1988 | NIAAA: Prenatal Alcohol Exposure and Offspring Development Grants for Development of Statistical Methods and Analysis of Data from the Seattle Longitudinal Study on Alcohol and Pregnancy; PI: Prof. Ann P. Streissguth, Psychiatry & Behav. Sci. |
| 1985 | PI on Contract Funding Graduate Student RA Russell Millar Doing Research on Estimation Methods for Mixed Stock Fisheries |
| 1985–1987 | SIMS/EPA Cooperative Agreement for Statistical Research in Environmetrics and Problems of Acid Deposition; co-PI with Prof. P. Guttorp at the University of Washington and Collaborative Researchers at the University of British Columbia, Stanford University, and the Rand Corporation |
| 1987 | Washington Department of Fisheries Contract for Further Development of the Nisqually Chum In-season Run Size Estimation Model and Program; PI (co-investigator Dr. M. L. Thompson) |
| 1987–1990 | EPRI (Electric Power Research Institute) Contract for Research on Global Nonparametric Estimation of Spatial Covariance Patterns; co-PI with Prof P. Guttorp; $164K/3 yrs. |
| 1987–1990 | SIMS/EPA Cooperative Agreement for Statistical Research on Problems of Acid Deposition; co-PI with Prof. P. Guttorp; $173K/3 yrs. |
| 1988–1989 | ADAI (Alcohol and Drug Abuse Institute, University of Washington) Grant for Study of First Trimester Fetal Marijuana Exposure and Facial Dysmorphogenesis; PI: Dr. Sterling K. Clarren, Pediatrics |
| 1988–1993 | NIAAA Prenatal Alcohol Exposure and Offspring Development; PI: Prof. Ann P. Streissguth, Psychiatry & Behav. Sci. |
| 1990–1991 | Washington State Department of Ecology Waste Sampling Plan; $3.5K |
| 1991–1992 | University of Washington Orthodontic Alumni Fund Analysis of the Long-Term Stability of Arch Form in Orthodontically Treated Patients; $6K |

1993–1995 NIAAA Prenatal Alcohol Exposure and Offspring Development; PI: Prof. Ann P. Streissguth, Psychiatry and Behav. Sci.

1993–1995 EPRI (Electric Power Research Institute) Contract for Research on Methods for the Operational Evaluation of an Air Quality Model; co-PI with Prof P. Guttorp; $257K/2 yrs.

1993 INRA (Insitut Nationale de la Recherche Agronomique) Grant for Research on Spatial Statistics and Environmental Monitoring Data; 51K FF/3 mths.

1994–1995 Washington Technology Center Software System for Cardiac Multimedia Data; PI: Dr. Florence H. Sheehan, M.D.

1995–1999 NIAAA Prenatal Alcohol Exposure and Offspring Development; PI: Prof. Ann P. Streissguth, Psychiatry & Behav. Sci.; $1,500K/4 yrs.

1995–1997 NSF Integrating Heterogeneous Geophysical Data by Combining Error Structures: An Interdisciplinary Pilot Project (DMS-9418904); co-PI with Dr. Gad Levy (University of Washington and Oregon State University) and Dr. Calton Pu (Oregon Graduate Institute) ; $88K/2 yrs. (to OSU)

1995–1996 UW RRF Automatic Construction of 3D Heart Models from Ultrasound Images; PI; $15K/1 yr.

1999–2000 UW ADAI Brain Morphometry in FAS/FAE and Normal Subjects; $15K (1999)

1996–2001 NIAAA Neuroanatomic-Psychologic Analyses of FAS/FAE Deficits; PI: Prof. Ann P. Streissguth, Psych. and Behavioral Sci. (current support at 20%); $1,130K/4 yrs.

1997–2001 EPA National Research Center for Statistics and the Environment; PI for projects on spatio-temporal modeling and the operational evaluation of air quality models. Co-Investigator on various other NRCSE grants (current support at approx 25%)

***Current:***

1999–2004 NIAAA Alcohol Intake During Pregnancy: Offspring Development; PI: Prof Ann P. Striessguth, Psychiatry and Behavioral Sciences (current support at 20%); $2,000k/5 yrs.

2002–2003 EPA Use of Kriging to Develop Ambient Air Concentration Estimates for Ozone for 1986–1994 for 83 Counties in the U.S. Contract with the Center for Statistical Consulting; $85K (20% support)

2002–2004 NIAAA Functional MRI of Cognitive Activation in FAS/FAE PI: Dr. Paul D. Connor (10% support); $740K/3 yrs.

***Grant Proposals Pending:***

2002–2006 NIH Ultrasound Segmentation for Prostate Brachytherapy; PI: Dr. Yongmin Kim (5% support); $1,204K/4 yrs.

2003–2006 NIAAA Methylphenidate and Dextroamphetamine in FASD; PI: Dr. Kieran O'Malley (3% support); $371K/3 yrs.

2003–2006 NIAAA Neuroanatomic-Psychologic Analyses of FAS/FAE Deficits; PI: Prof. Ann P. Streissguth, Psych. and Behavioral Sci. (25% support); $918K/3 yrs.

**Research Papers in Refereed Journals:**

1 Freiberger WF, Grenander U, and Sampson PD: Patterns in Program References. IBM Journal of Research and Development, 19, 230-243, 1975.

2 Sampson PD: Comment on 'Splines and Restricted Least Squares'. Journal of the American Statistical Association, 74, 303-305, 1979.

3 Sampson PD: Dental Arch Shape: A Statistical Analysis Using Conic Sections. American Journal of Orthodontics, 79, 535-550, 1981.

4 Sampson PD: Fitting Conic Sections to 'Very Scattered' Data: An Iterative Refinement of the Bookstein Algorithm. Computer Graphics and Image Processing, 18, 97-108, 1982.

5 Barrett TB, Sampson PD, Owens GK, Schwartz SM, Benditt EP: Polyploid Nuclei in Human Artery Wall Smooth Muscle Cells. Proceedings of the National Academy of Sciences, 80, 882-885, 1983.

6 Sampson PD: Statistical Analysis of Arch Shape with Conic Sections. Biometrics, 39, 411-424, 1983.

7 Sampson PD, Siegel, AF: The Measure of Size Independent of Shape for Multivariate Lognormal Populations. Journal of the American Statistical Association, 80, 910-914, 1985.

8 Little RE, Asker RL, Sampson PD, Renwick JH: Fetal Growth and Moderate Drinking in Early Pregnancy. American Journal of Epidemiology, 123, 270-278, 1986.

9 Bertram JF, Sampson PD, Bolender RP: Influence of Tissue Composition on the Final volume of Rat Liver Blocks Prepared for Electron Microscopy. Journal of Electron Microscopy Technique 4, 303-314, 1986.

10 Streissguth AP, Barr HM, Sampson PD, Parrish-Johnson JC, Kirchner GL, Martin DC: Attention, Distraction and Reaction Time at 7 Years and Prenatal Alcohol Exposure. Neurobehavioral Toxicology and Teratology 8, 717-725, 1986.

11 Streissguth AP, Treder RP, Barr HM, Shepard TH, Bleyer WA, Sampson PD, Martin DC: Aspirin and Acetaminophen Use by Pregnant Women and Subsequent Child IQ and Attention Decrements. Teratology 35, 211-219, 1987.

12 Clarren SK, Sampson PD, Larsen J, Donnell DJ, Barr H, Bookstein FL, Martin DC, Streissguth AP: Facial Effects of Fetal Alcohol Exposure: Assessment by Photographs and Morphometric Analysis. American Journal of Medical Genetics 26, 651-666, 1987.

13 Vong RJ, Moseholm L, Covert DS, Sampson PD, O'Loughlin JF, Stevenson MN, Charlson RJ, Zoller WH, Larson TV: Spatial and Temporal Variations in Urban Rainwater Chemistry: Changes in pH and Sulfate Associated with the Closure of a Copper Smelter. Journal of Geophysical Research, 93D6, 7169-7179, 1988.

14 Sheller B, Clarren SK, Astley SJ, Sampson PD: Morphometric Analysis of Macaca nemestrina Exposed to Ethanol During Gestation. Teratology, 38, 411-417, 1988.

15 Streissguth AP, Barr HM, Sampson PD, Darby BL, Martin DC: IQ at Age Four in Relation to Maternal Alcohol Use, Caffeine Use, and Smoking During Pregnancy, Developmental Psychology, 25, 3-11. (Abstracted in Science News, 135, 68.), 1989.

16 Streissguth AP, Barr HM, Sampson PD, Bookstein FL, Darby BL: Neurobehavioral Effects of Prenatal Alcohol: Part I. Research Strategy, Neurotoxicology and Teratology, 11, 461-476, 1989.

17 Sampson PD, Streissguth AP, Barr HM, Bookstein FL: Neurobehavioral Effects of Prenatal Alcohol: Part II. Partial Least Squares Analyses , Neurotoxicology and Teratology, 11, 477-491, 1989.

18 Streissguth AP, Bookstein FL, Sampson PD, Barr HM: Neurobehavioral Effects of Prenatal Alcohol: Part III. PLS Analyses of Neuropsychologic Tests, Neurotoxicology and Teratology, 11, 493-507, 1989.

19 Fujisaki JM, van Belle G, Sampson PD: Size and Shape Variables in the Presence of Covariates: An Application to the Sudden Infant Death Syndrome, Journal of Clinical Epidemiology, 43, 173-180, 1990.

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# White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples

## Response to Comments of the P.H. Glatfelter Company and WTMI Company to the Proposed Plan for the Lower Fox River and Green Bay

January 2002


***This Document has been Prepared by***

Wisconsin Department of Natural Resources



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# WHITE PAPER NO. 2 – EVALUATION OF NEW LITTLE LAKE BUTTE DES MORTS PCB SEDIMENT SAMPLES

## ABSTRACT

During the public comment period for the *Final Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a), the *Final Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001), P.H. Glatfelter Company and WTMI Company (formerly Wisconsin Tissue Mills, Inc.) submitted additional sediment sampling data to the Wisconsin Department of Natural Resources (WDNR) for Little Lake Butte des Morts. These data were submitted as part of the comments and were also incorporated into the general comments submitted on behalf of the Fox River Group. Additional data collected in August 2002 were also submitted to WDNR. To evaluate potential changes in the conclusions presented in the RI, the new data points were plotted on to the existing RI bed maps, and the bed maps for OU 1 were re-interpolated. They were further analyzed through the use of scatter plots. This White Paper concluded that the additional data supported the conclusions of the RI/FS. There was essentially no change in the surface-weighted average concentrations using the re-interpolated bed maps. The new data re-emphasized the need for refining the final remedial footprint in the design phase. Finally, that the new data did not support the commenters' position that surface sediment concentrations are decreasing in Little Lake Butte des Morts.

## PURPOSE

The purpose of this memorandum is to evaluate the potential impacts to the interpretation presented in the RI/FS of the additional sediment sampling data submitted to the WDNR for Little Lake Butte des Morts (Operable Unit 1) as part of the public comments. These data were submitted as part of the comments by P.H. Glatfelter Company, by WTMI Company, and were also incorporated into the general comments submitted on behalf of the Fox River Group. In addition, a set of data collected in 2002 at Deposit A on behalf of P.H. Glatfelter were submitted outside of the comment period, but are also included in this evaluation.

## DATA

Data provided to WDNR during the public comment period were the result of sampling events undertaken by Blasland, Bouck and Lee (BBL) on behalf of the P.H. Glatfelter Company, and by CH2M HILL for WTMI. Data were provided to WDNR in three formats: hard copy data reports (Form 1 and/or the reports included with the respective company comments), electronic data files from the individual companies, and the FoxView database assembled for the Fox River Group.

For the WTMI data, only Form 1s were submitted to WDNR for review. Pertinent information that is necessary to validate data, including an approved Sampling and Analysis Plan, core logs, methods and verification procedures for horizontal and vertical control during sampling, and a full data package were not part of any submittal given to WDNR. A separate data validation exercise for the Form 1 data was undertaken for the WTMI-collected soil/sediment (and one set of woodchip) samples in 2000 and 2001. While requested by WDNR, data validation reports were not provided. The information reviewed consisted of data validation worksheets and annotated sample result summary forms. The results of the review are given in the *Addendum to the Data Management Summary Report* (EcoChem, 2002), which is included in Appendix A of the RI. Based upon the Form 1 review only, the overall data appear to be of acceptable quality. However, given the lack of a complete submittal, these data are considered not fully validated, but may be used to qualitatively support the evaluation of Little Lake Butte des Morts sediments.

BBL collected sediment samples in Little Lake Butte des Morts in 2001. Samples were analyzed for PCB congeners (one data set), PCB Aroclors, total organic carbon (TOC), and grain size. The data set consisted of 158 samples. A complete set of validation worksheets and a report were submitted with this data package. These data were also independently reviewed and are discussed in the *Addendum to the Data Management Summary Report* (EcoChem, 2002). Overall, the data were found to be of acceptable quality and are usable for the intended purpose.

Foth and Van Dyke collected sediment samples in Little Lake Butte de Morts on behalf of P.H. Glatfelter in August 2002 at Deposit A. Samples were analyzed for PCB Aroclors and TOC. The data set consisted of 47 samples. The electronic data files submitted included core logs. However, the data validation reports were not provided. Therefore, while the PCB data may be used at face value for interpolation in this White Paper, they are used with the caveat that the data and interpolations are considered to be draft.

## PROCEDURES

Evaluation of the new data, relative to the RI/FS bed maps proceeded in two ways. First, to evaluate potential changes in the conclusions presented in the RI, the 2000 and 2001 data points were plotted onto the existing RI bed maps. These new data were compared, as well, to the existing data to evaluate if there were, in fact, any substantive differences that would alter the conclusions. Secondly, the 2000, 2001, and 2002 data were used to provide a re-interpolation of the PCB bed maps. The re-interpolated bed maps were then used to compare to the "new" surface-weighted average concentration, required remedial areas, and potential removal volumes at the 1 ppm remedial action level.

### Evaluation of the 2000 and 2001 OU 1 Data

To begin the process, it was necessary to create an electronic set of data that included the coordinates, sample interval, and resultant total PCB concentrations for each new sample date. WDNR had received a working copy of the FoxView database, and it was initially thought that querying that database would provide the information to complete the evaluation. However, FoxView did not contain the CH2M HILL data for Little Lake Butte des Morts. As such, the electronic data files that were provided to WDNR as part of the WTMI response were placed into a new spreadsheet with the files generated from FoxView. The spreadsheet created was reviewed to ensure data were not duplicated. Upon further review, it was determined that additional data were not in either electronic format provided. Therefore, a 100 percent check was undertaken against the hard copy data provided. The resultant graphics generated were subsequently checked against graphics provided by the respective companies.

The following steps summarize the procedure for developing the figures with the new PCB sampling data.

1. The Access database file and Excel file were converted to a dbf format file.

2. The latitude/longitude data provided in the Access database file and Excel file were in degrees, minutes, and seconds format. The data were converted to decimal degrees coordinates.

3. The data were filtered to show records by station ID and PCB sampling results for primary sediment samples in the Little Lake Butte des Morts Reach. The resulting dbf file was converted to a shape file and projected in Wisconsin Transverse Mercator (WTM) projection. Separate shape files were created for each depth interval (0 to 10 cm, 10 to 30 cm, 30 to 50 cm, 50 to 100 cm, and 100 to 150 cm).

4. The PCB data in the data set were not presented in a consistent format. Certain PCB samples were provided solely as individual Aroclors, while other samples were reported as total PCBs. To present data in a manner consistent with the RI, all data were expressed as total PCBs. A script was written in ArcView GIS that calculated total PCB values for a particular sample ID by summing the individual Aroclors for that particular location. Consistent with the RI, non-detected Aroclors were calculated as 50 percent of the method detection limit (MDL) for samples with non-detect values. For sample locations where total PCB values were provided, the script selected either the given total PCB value for a particular sampling location or 50 percent of the MDL for samples with non-detect values.

5. Scripts on all shape files created in Step 3 were run to sum up the PCB values for each sampling location. Running the script creates a new table with the total PCB values. Separate shape files were created for the script output tables based on depth interval and the shape files were projected in WTM projection to represent the new PCB sampling locations.

6. The new PCB sampling locations were overlaid on the interpolated PCB distribution map from the Draft 2001 RI/FS for each depth interval for comparison purposes. Five maps, corresponding to the five depth intervals, were generated for Little Lake Butte des Morts with the new sampling data.

7. The output table from the script with total PCB values was randomly checked and manual calculations completed by summing individual PCB Aroclors to verify the results obtained from the script. During the process of quality assurance (QA), certain sampling locations (BBL) were identified to have two total PCB values for the same sample ID and depth interval. The higher of the two PCB values was selected for presenting the data on the map. Also certain sampling data (approximately six sampling locations by BBL) were identified with the sampling depth range specified as 10 to 100 cm. The PCB samples were assumed to be collected from the 50- to 100-cm depth range for presentation purposes.

8. WTMI provided a map with the new PCB sampling points presented in the report Appendix to WTM Comments I dated January 2002. The map generated by WDNR with the new sediment sampling data was checked against the map provided by WTMI as part of QA.

### Re-Interpolation of PCB Bed Maps for OU 1

Re-interpolation of the OU 1 PCB bed maps followed the procedures defined in Technical Memorandum 2e in the *Final Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (WDNR and RETEC, 2002) and described in the RI. The P.H. Glatfelter and WTMI 2000, 2001, and the 2002 data were combined with the RI data set. The filtering process for data as described in the supplemental memorandum to Technical Memorandum 2e, dated October 26, 2000, was performed with the combined data sets. This procedure involved using all the new PCB data and filtering existing PCB data so that only data points that fall beyond the 133-meter radius of the new PCB data points are retained. Table 1 lists all the PCB data points that were retained after the filtering procedure and Table 2 lists all the PCB data points that were discarded after the filtering procedure. The PCB interpolation was completed in ArcView GIS utilizing data from Table 1.

The newly created bed maps were clipped to previously masked grids, which represented the presence of soft sediment within the Lower Fox River. This resulted in the creation of new PCB bed maps for six depth intervals (0 to 10 cm, 10 to 30 cm, 30 to 50 cm, 50 to 100 cm, 100 to 150 cm, and 150 to 200 cm).

### Comparative Trends

In addition to evaluating the new data relative to the existing bed maps, scatter plots were created comparing the existing data to the 2000 through 2002 data.

## RESULTS

Figures 1 through 5 show the locations and corresponding total PCB concentrations for the samples collected by CH2M HILL (circles) and BBL (squares). Most of the samples collected were focused on better delineating PCB concentrations in deposits A, B, C, POG, and E. Depth intervals and concentration ranges represented correspond to those used in the RI. As noted above, for at least the CH2M HILL data, all points were checked against figures submitted with the WTMI response, with 100 percent agreement in points and concentrations.

Figures 6 through 10 represent the data points plotted onto the existing bed maps for the RI. The important conclusions from these comparisons are as follows:

- Within the surface sediments (0 to 10 cm), most of the area within Little Lake Butte des Morts exceeds the 1,000 ppb action level. This was, and remains true for the largest deposits A/B, C, E, and POG.

- Higher surface concentrations of total PCBs are reported for deposits A/B, and POG. Concentrations of PCBs exceeded 50,000 ppb in deposits A and POG, where the RI had placed those at between 10,000 and 50,000 ppb.

- The Toxic Substance Control Act (TSCA) PCB threshold of 50,000 ppb is exceeded for several of the new stations collected at deposits A and POG. This includes one of the highest PCB concentrations ever measured in Little Lake Butte des Morts at Deposit POG of 385,000 ppb. At Deposit POG, TSCA material is found as deep as the 100- to 150-cm profile. This will impact the proposed remedy for these deposits in that TSCA handling and disposal requirements were not included in the FS for Deposit POG.

- The new data suggest that Deposit E surface sediments are relatively uniform in concentration, between 1,000 and 5,000 ppb. The bed maps within the RI show an area of total PCBs exceeding 10,000 ppb. The interpolation was based upon a single data point of approximately 46,000 ppb collected in 1994. The supplemental data collected within that same area are all less than 5,000 ppb, but still greater than the Remedial Action Level (RAL).

- PCB concentrations exceeding the RAL for some deposits may be less, or more than estimated in the RI/FS. For example, PCB concentrations at Deposit A exceed the RAL through the 30-cm depth profile. However, while the Figure 8 RI grid maps show PCB concentrations requiring remediation to a depth of cut of 100 cm, more recent data have PCB concentrations of less than 50 ppb. In contrast, Figures 8 through 10 show that PCBs exceeding the RAL are deeper than included in the RI/FS for deposits POG (150 cm) and E (100 cm).

The re-interpolated PCB bed map for OU 1 at all depth layers is presented in Plate 1. Figure 11 shows a comparison of the surface sediment PCB concentrations from the RI, and from the re-interpolation. The differences in the bed maps reflect the bullet points listed above. Between the two bed maps, there is no appreciable change in the surface-weighted average concentration; the SWAC for the RI was reported as 4.17 ppm, whereas the recalculated SWAC is 4.23 ppm. Within the RI, the area falling within the 1 ppm ppb action level totaled 527 acres (2,133,979 $m^2$), whereas in the re-interpolated bed maps the area is approximately 493 acres (1,993,087 $m^2$). Thus, there is a reduction of roughly 6 percent in the overall area.

As an alternate way of viewing the data, scatter plots of the surface sediment data for the four deposit groups collected since 1989 are shown on Figure 12. These are not intended to show trends over time, but rather to emphasize that in the surface sediments, these new data are generally within the range and consistent with data collected previously. It is of interest to note that in the plot for Deposit E, a single sample in 1994 was significantly higher than all of the other data collected in that same year, but that the other data collected subsequently was fairly similar. In the Deposit POG plot, the opposite condition occurs; the more recently collected data shows higher concentrations than the existing concentration, and one single sample is significantly higher than any sample previously collected. This is also true of Deposit A, where the 2002-collected data show surface sediment concentrations exceeding all other values previously reported.

## CONCLUSIONS

The additional data submitted on behalf of P.H. Glatfelter Company and WTMI generally support the conclusion of the RI/FS and the Proposed Plan. Surface sediments within Little Lake Butte des Morts exceed the RAL of 1,000 ppb. The Proposed Plan-defined remedial actions at deposits A/B, C, POG, and E; these data support that decision.

These new data suggest that the final remedial footprints, both the horizontal and vertical profile, will be refined in the final design. The horizontal footprint for deposits A/B, C, and POG could be drawn larger than the existing bed maps indicate, whereas Deposit E may in fact represent a smaller area than defined in the RI. Depth of removal may be refined as well; the data suggesting that a shallower cut may be needed at deposits A/B and C, but deeper at deposits POG and E. The lack of submittal of important sampling data (e.g., core logs) did not allow for a complete analysis of the vertical increments. It is anticipated that WDNR will be collecting Site-specific information in the near future supporting the Design Phase of the removal to define the final footprint for remedial action. These new data will be very useful in helping to define either a remedial dredge prism, or a cap, depending upon the final Record of Decision for Operable Unit 1.

These new data do not support the position taken by the companies that surface sediment concentrations are decreasing within Little Lake Butte des Morts. A closer look at those data, relative to the bed maps, suggest that in some cases concentrations are lower, and in others higher. For example, within deposits A/B, and POG, higher sediment concentrations were measured than had ever been previously reported within the RI/FS. This is especially true in deposits A and POG (see Figure 6), where six new stations exceeded 50,000 ppb, and one station in Deposit POG with a surface concentration of 360,000 ppb. Samples collected in Deposit E, on the other hand, are lower than the single high concentration of 45,850 ppb collected in 1994. This combination of lower and higher observations suggest that this is more an issue of sampling variability, and not decreasing or increasing trends. Time trends in sediments and fish tissue concentrations were presented as an appendix to the RI entitled *Time Trends in PCB Concentrations in Sediment and Fish: Lower Fox River and Green Bay, Wisconsin*. Further refinement of those presentations are presented in the separate (*White Paper No. 1 – Time Trends Analysis* [Polissar et al., 2002]), which accompanies the overall *Responsiveness Summary, Lower Fox River and Green Bay, Wisconsin – Record of Decision, Operable Units 1 and 2* (WDNR and EPA, 2002).

## UNCERTAINTIES

The principal uncertainty in the analysis in this paper is in the lack of understanding on the methods for sampling and vertical control used by the respective contractors for the two paper companies. As noted previously, WDNR was not provided with any core logs or vertical control information that would help evaluate the interpretations given by the companies' data. This analysis took their data at face value for vertical depth and the conclusion drawn is that the additional data support the conclusions of the RI/FS.

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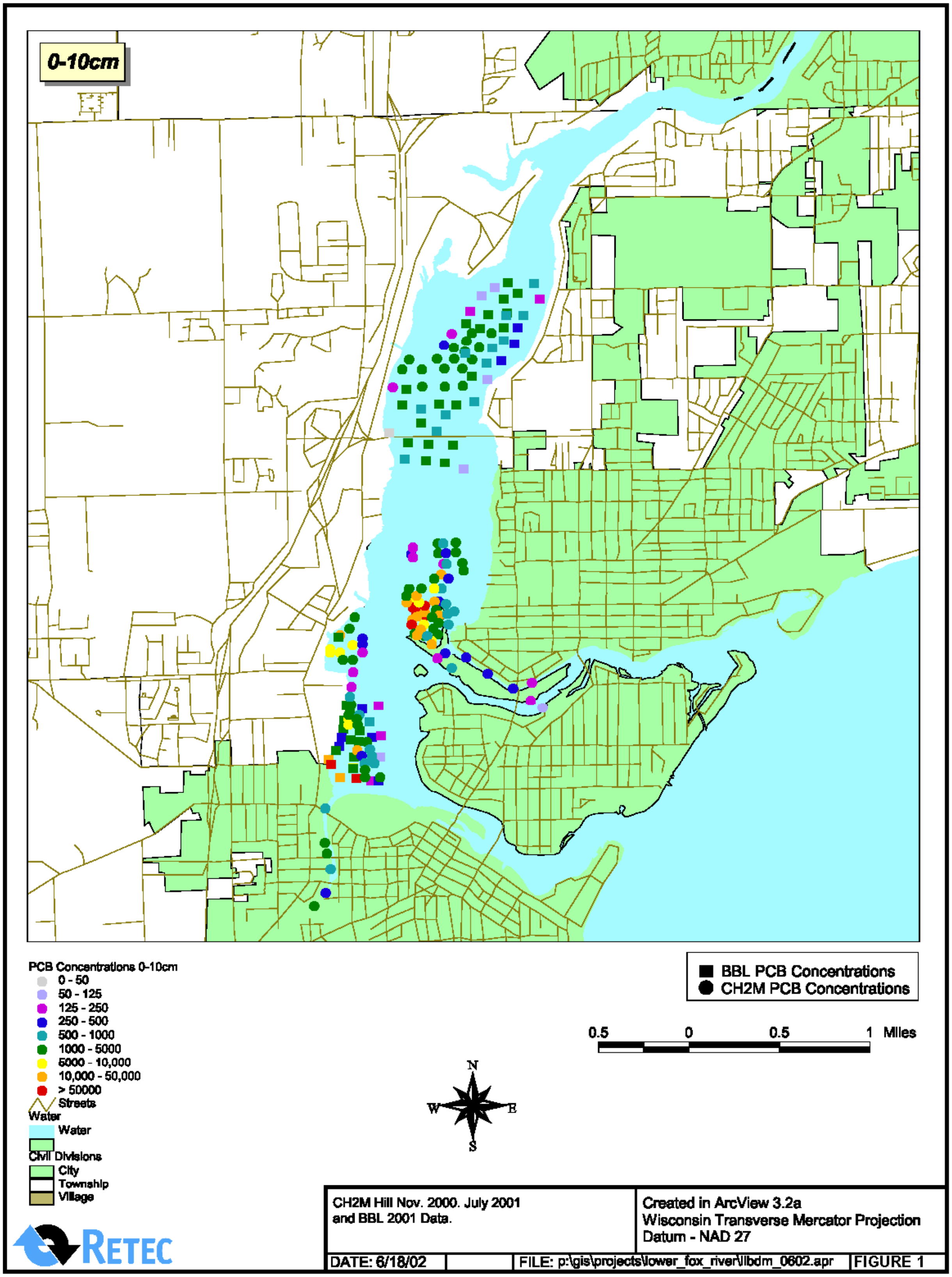
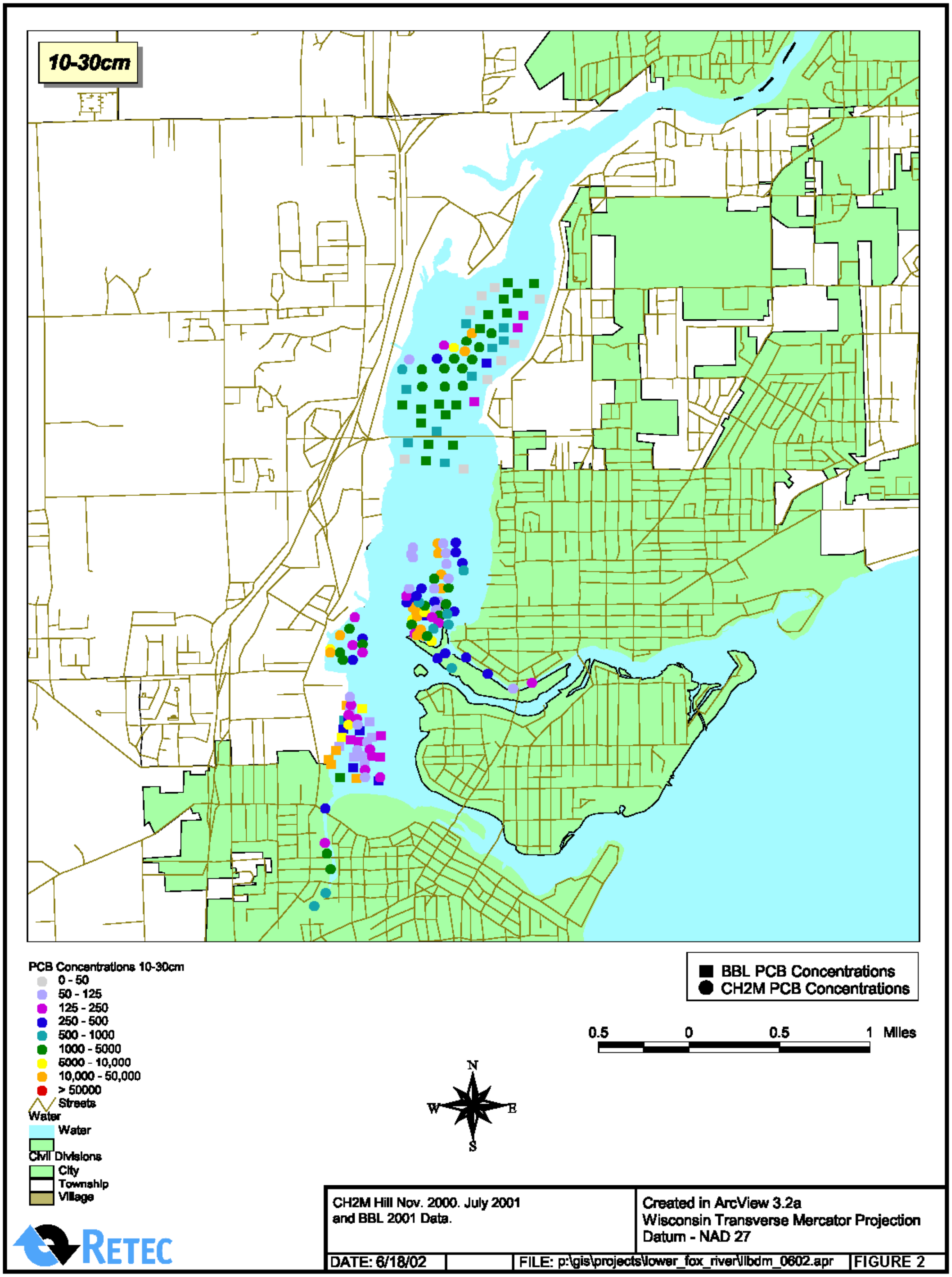
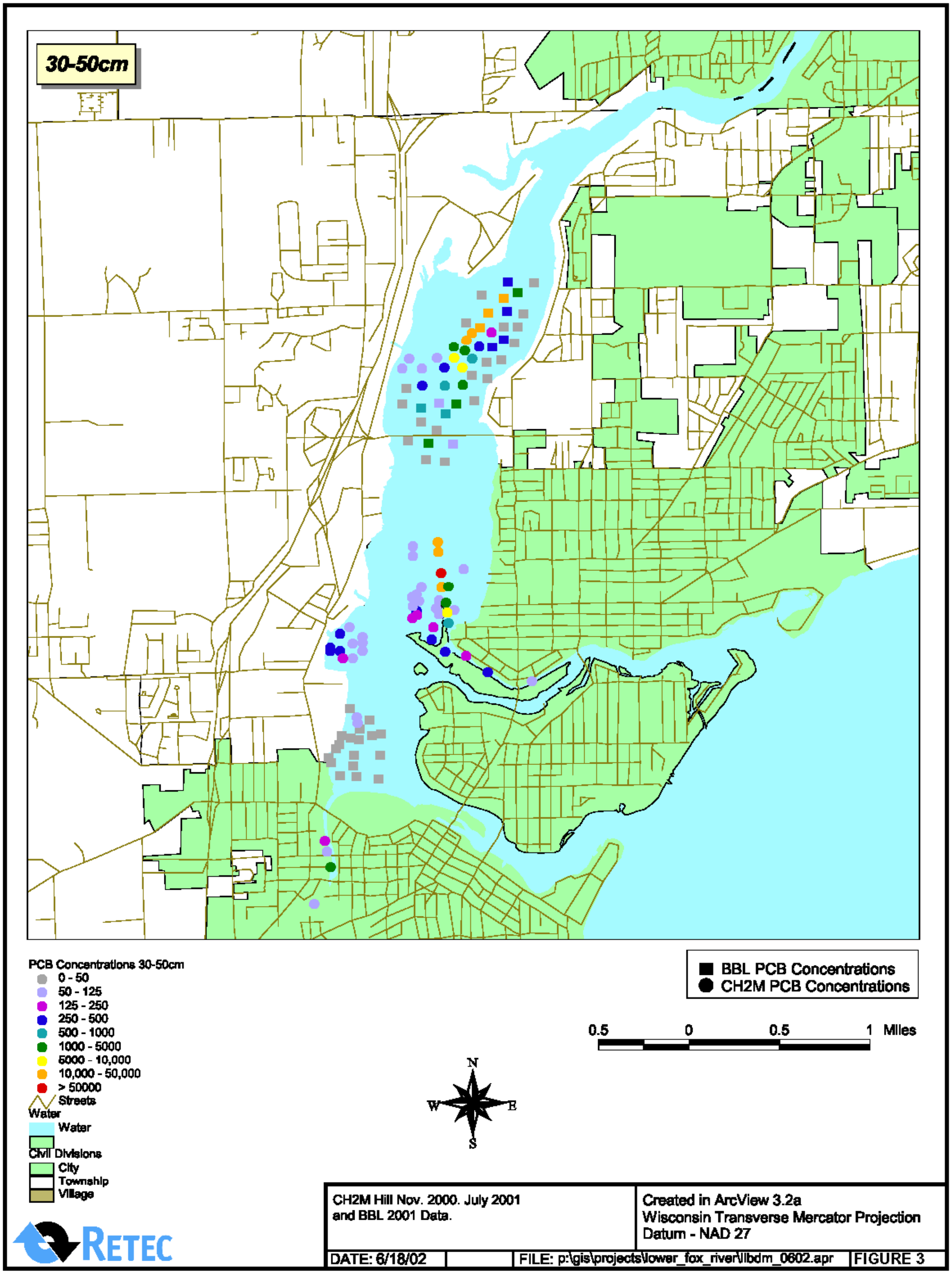
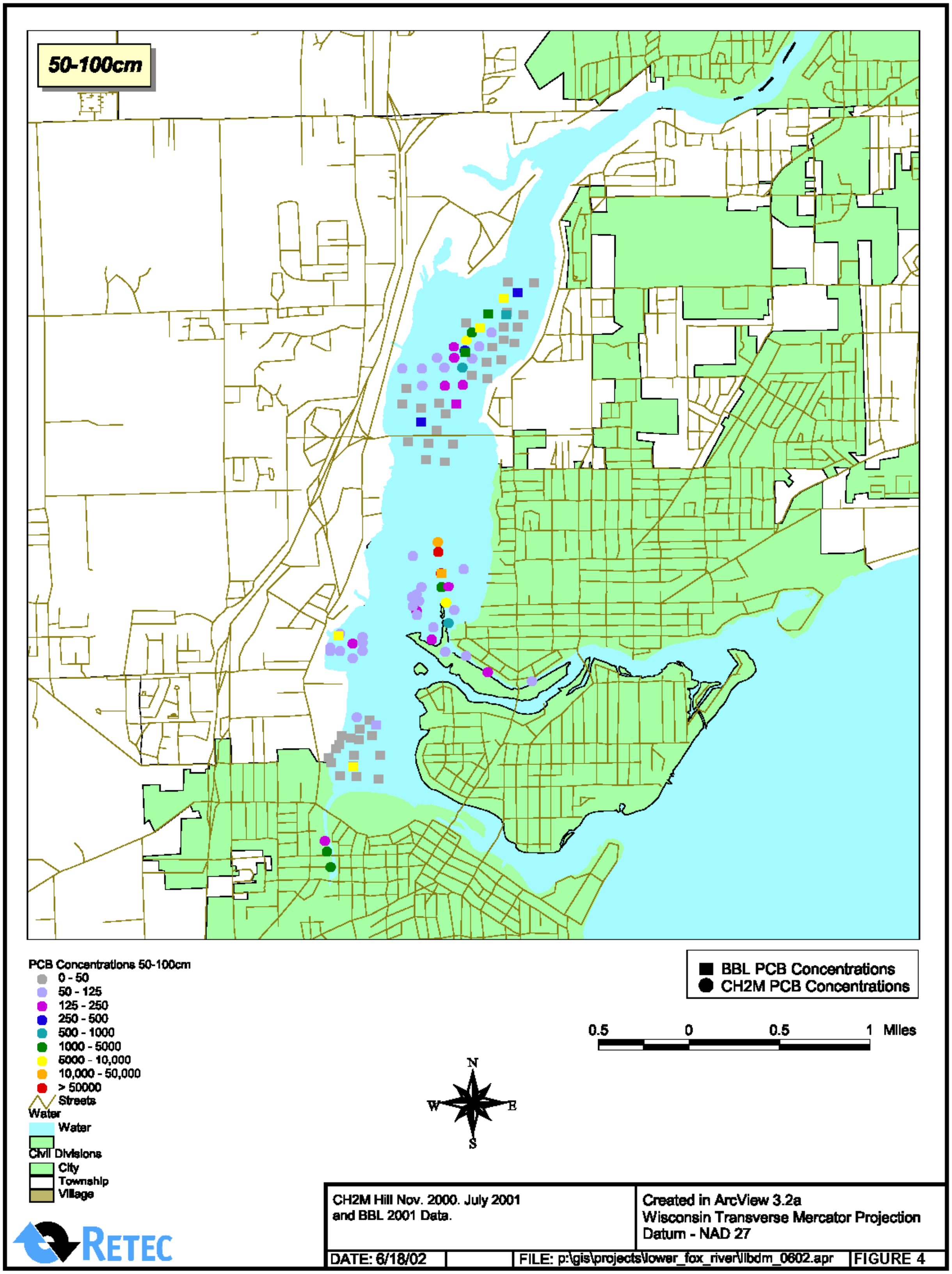
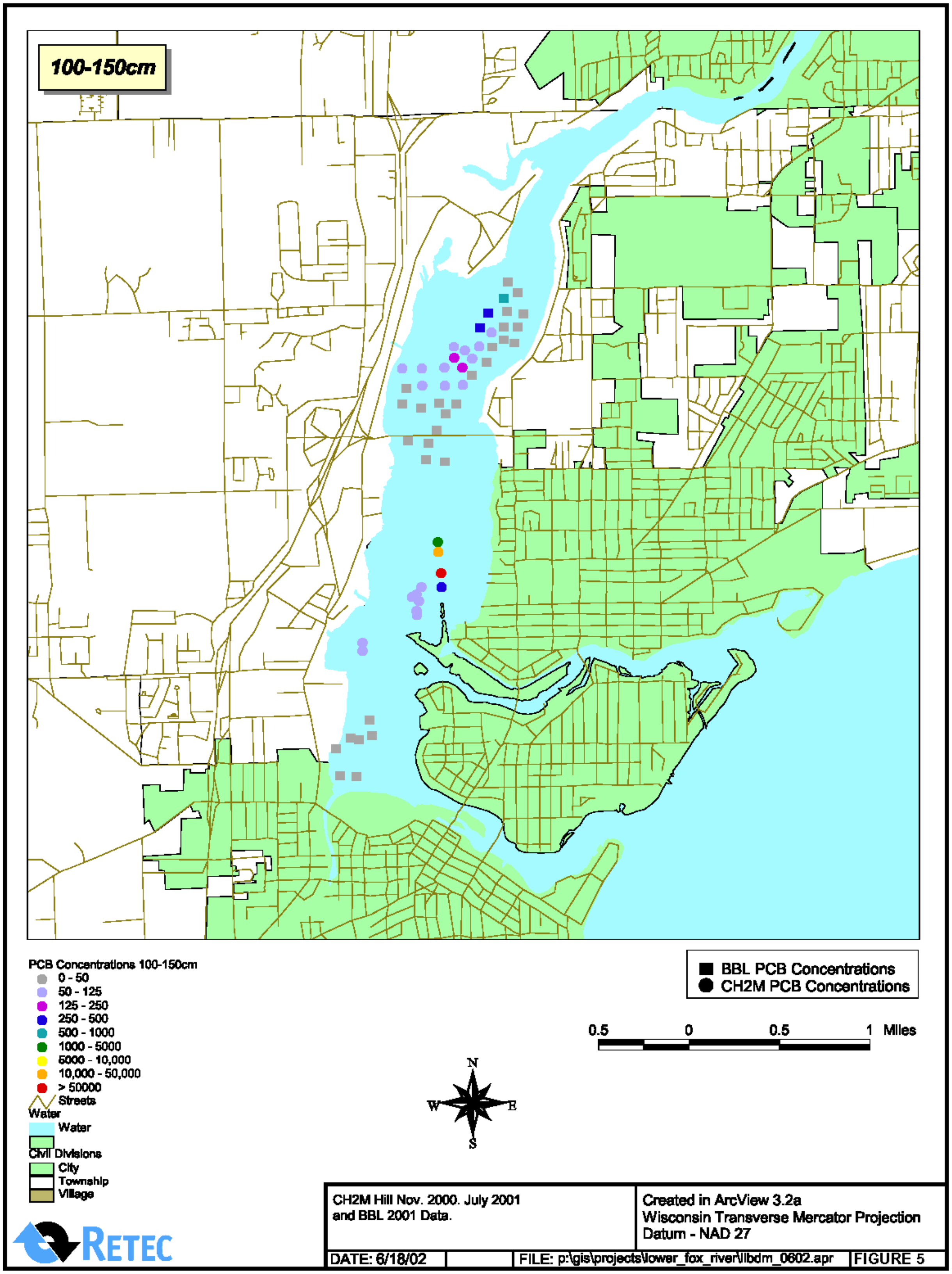

0-10cm
PCB Concentrations 0-10cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5 0 0.5 1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001
and BBL 2001 Data.
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 1



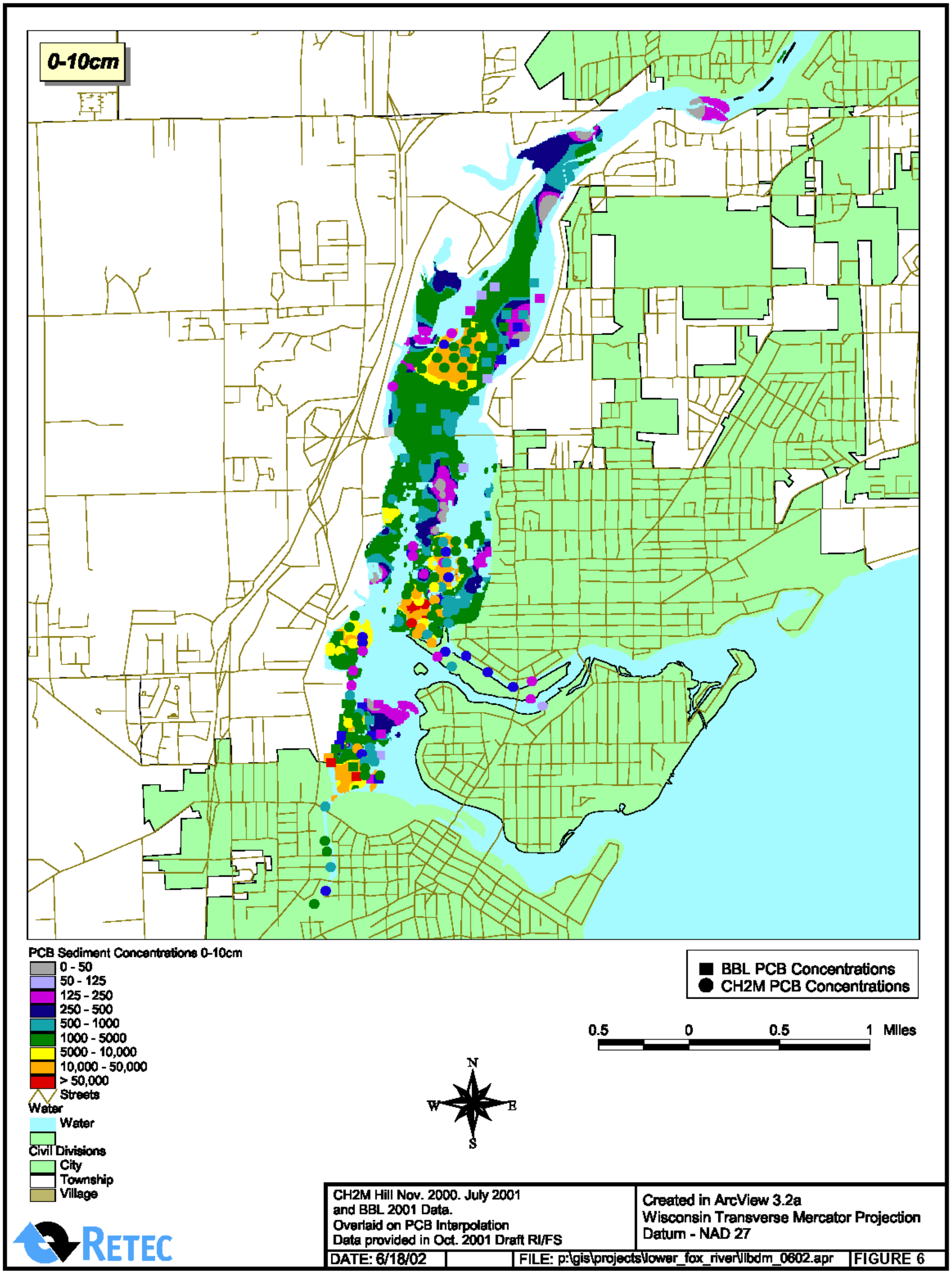

| CH2M Hill Nov. 2000. July 2001 and BBL 2001 Data. | Created in ArcView 3.2a Wisconsin Transverse Mercator Projection Datum - NAD 27 | |
|---|---|---|
| DATE: 6/18/02 | FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr | FIGURE 2 |

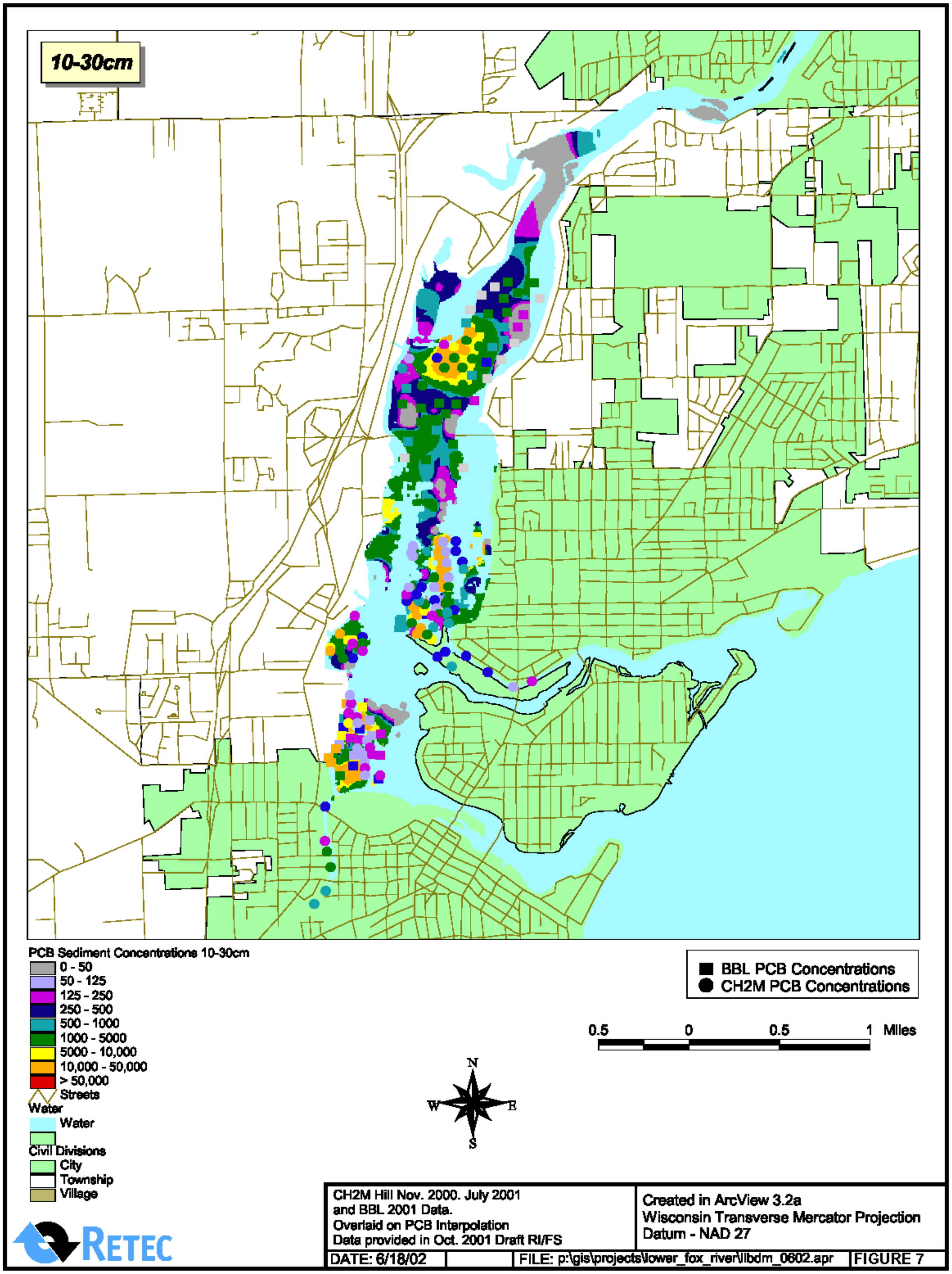

30-50cm
PCB Concentrations 30-50cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5
0
0.5
1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001 and BBL 2001 Data.
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 3

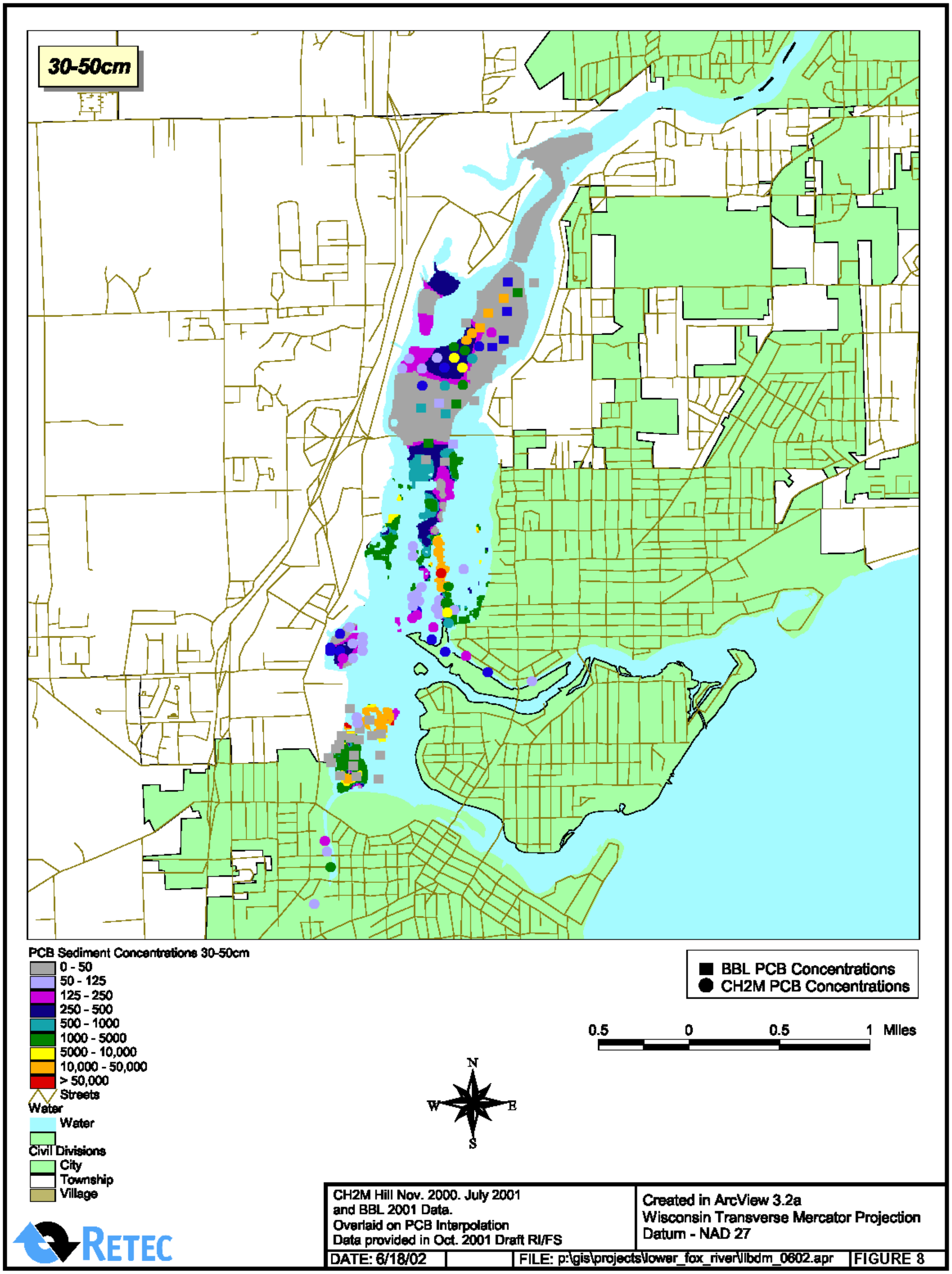

50-100cm
PCB Concentrations 50-100cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5
0
0.5
1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001 and BBL 2001 Data.
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 4

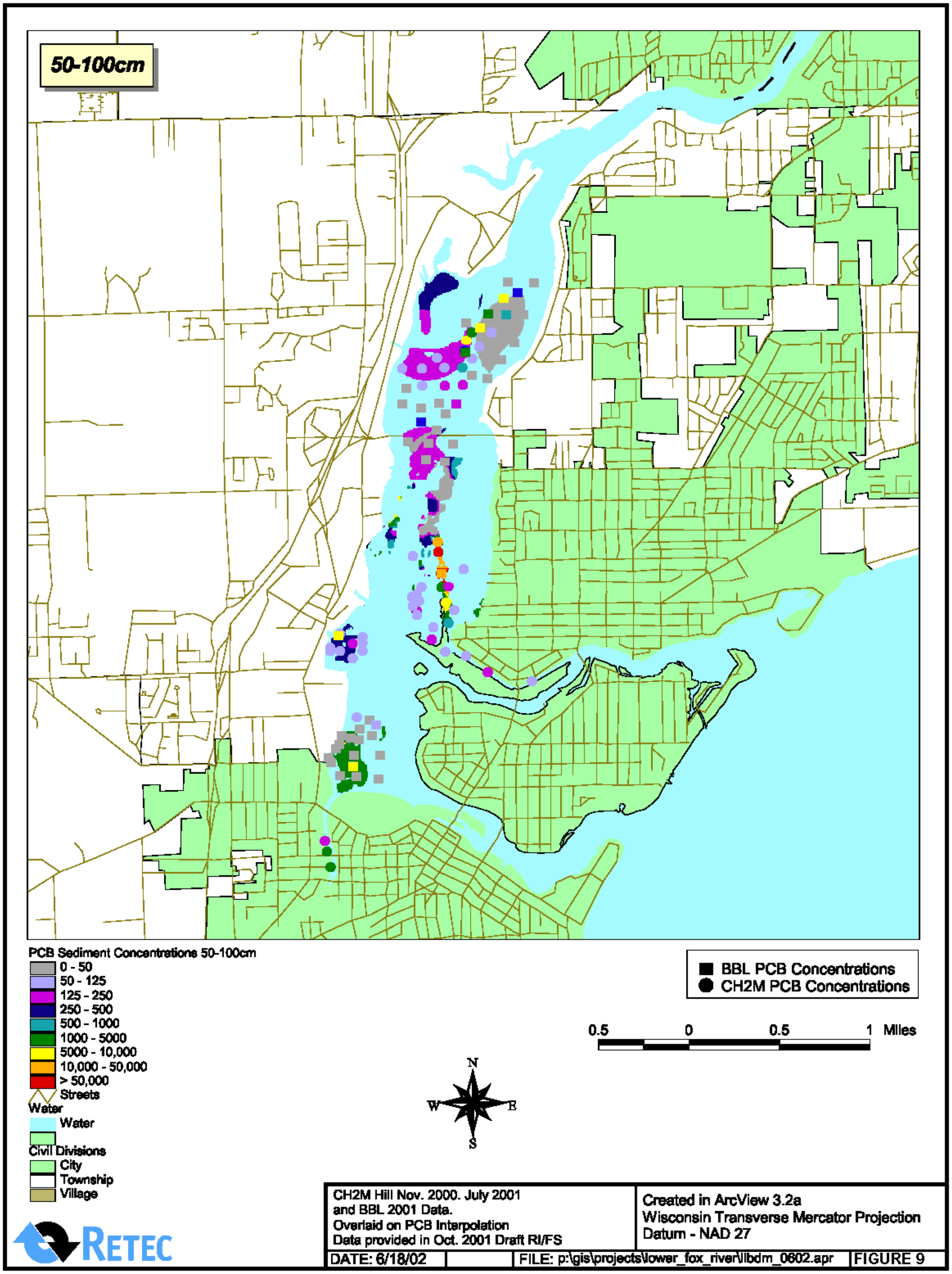


100-150cm
PCB Concentrations 100-150cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5 0 0.5 1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001
and BBL 2001 Data.
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 5


0-10cm
PCB Sediment Concentrations 0-10cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50,000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5 0 0.5 1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001
and BBL 2001 Data.
Overlaid on PCB Interpolation
Data provided in Oct. 2001 Draft RI/FS
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 6


10-30cm
PCB Sediment Concentrations 10-30cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50,000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5 0 0.5 1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001 and BBL 2001 Data.
Overlaid on PCB Interpolation Data provided in Oct. 2001 Draft RI/FS
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 7

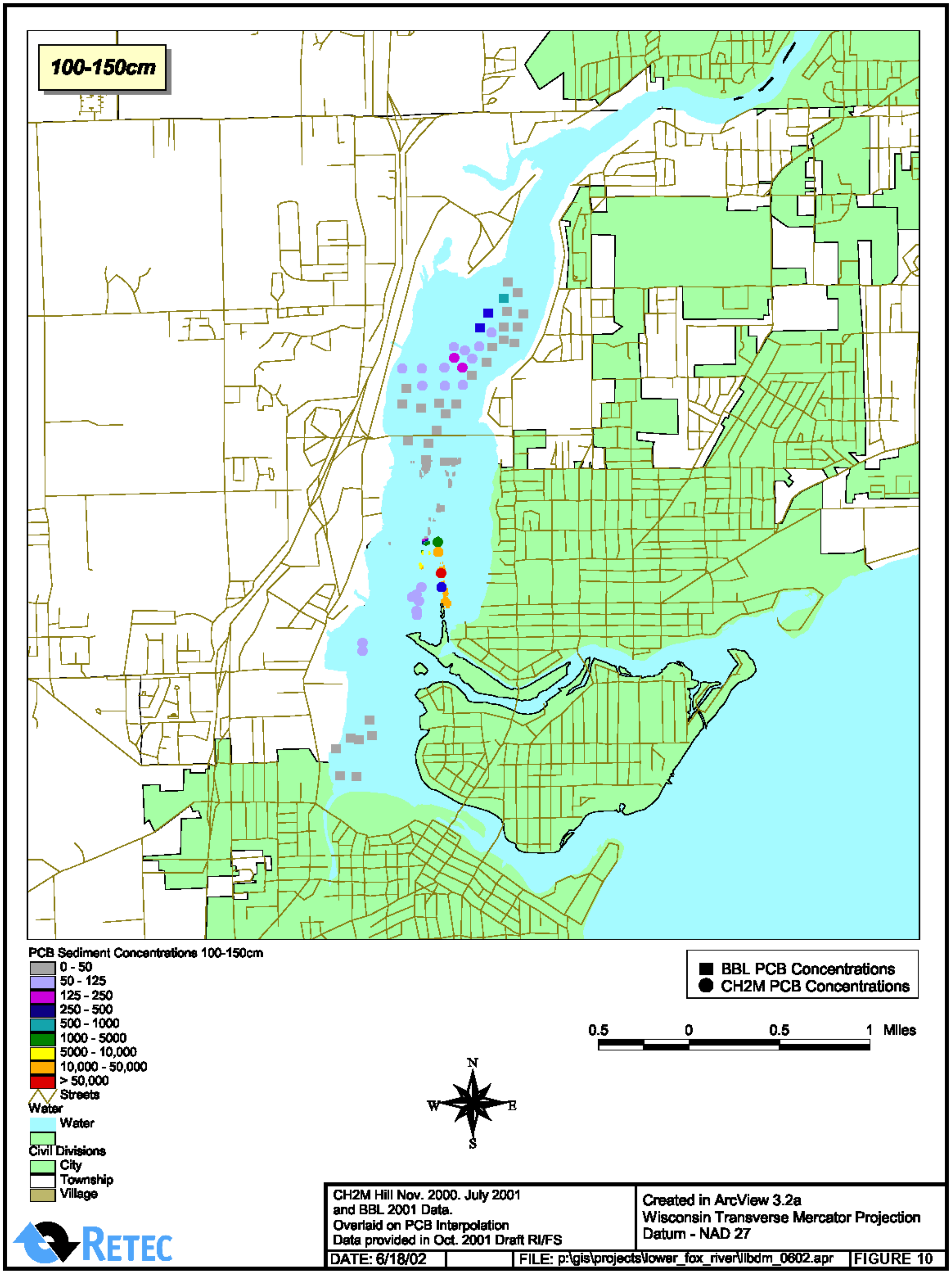

30-50cm
PCB Sediment Concentrations 30-50cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50,000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5 0 0.5 1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001
and BBL 2001 Data.
Overlaid on PCB Interpolation
Data provided in Oct. 2001 Draft RI/FS
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 8

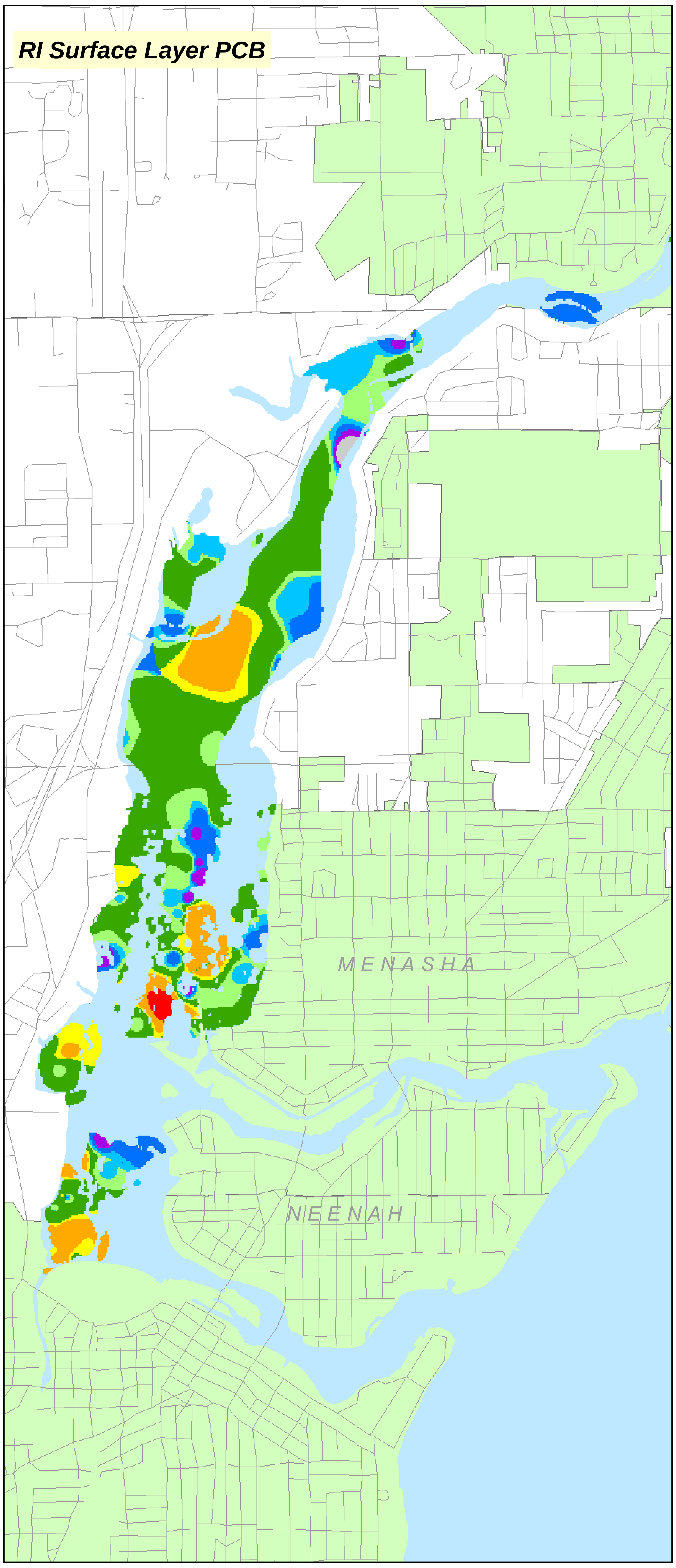


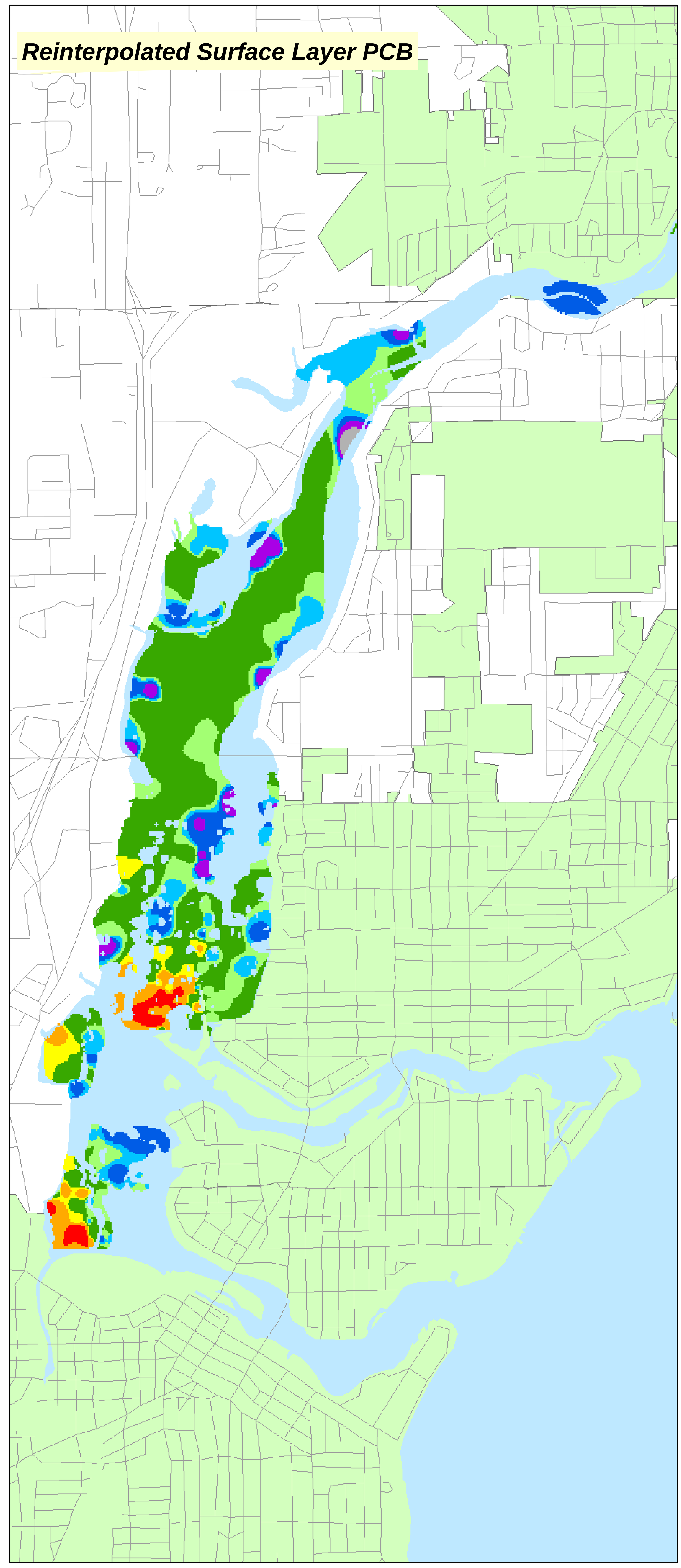

CH2M Hill Nov. 2000. July 2001 and BBL 2001 Data. Overlaid on PCB Interpolation Data provided in Oct. 2001 Draft RI/FS

Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27

DATE: 6/18/02 | FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr | FIGURE 9


100-150cm
PCB Sediment Concentrations 100-150cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50,000
Streets
Water
Water
Civil Divisions
City
Township
Village
BBL PCB Concentrations
CH2M PCB Concentrations
0.5
0
0.5
1 Miles
N
W
E
S
RETEC
CH2M Hill Nov. 2000. July 2001
and BBL 2001 Data.
Overlaid on PCB Interpolation
Data provided in Oct. 2001 Draft RI/FS
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE 10



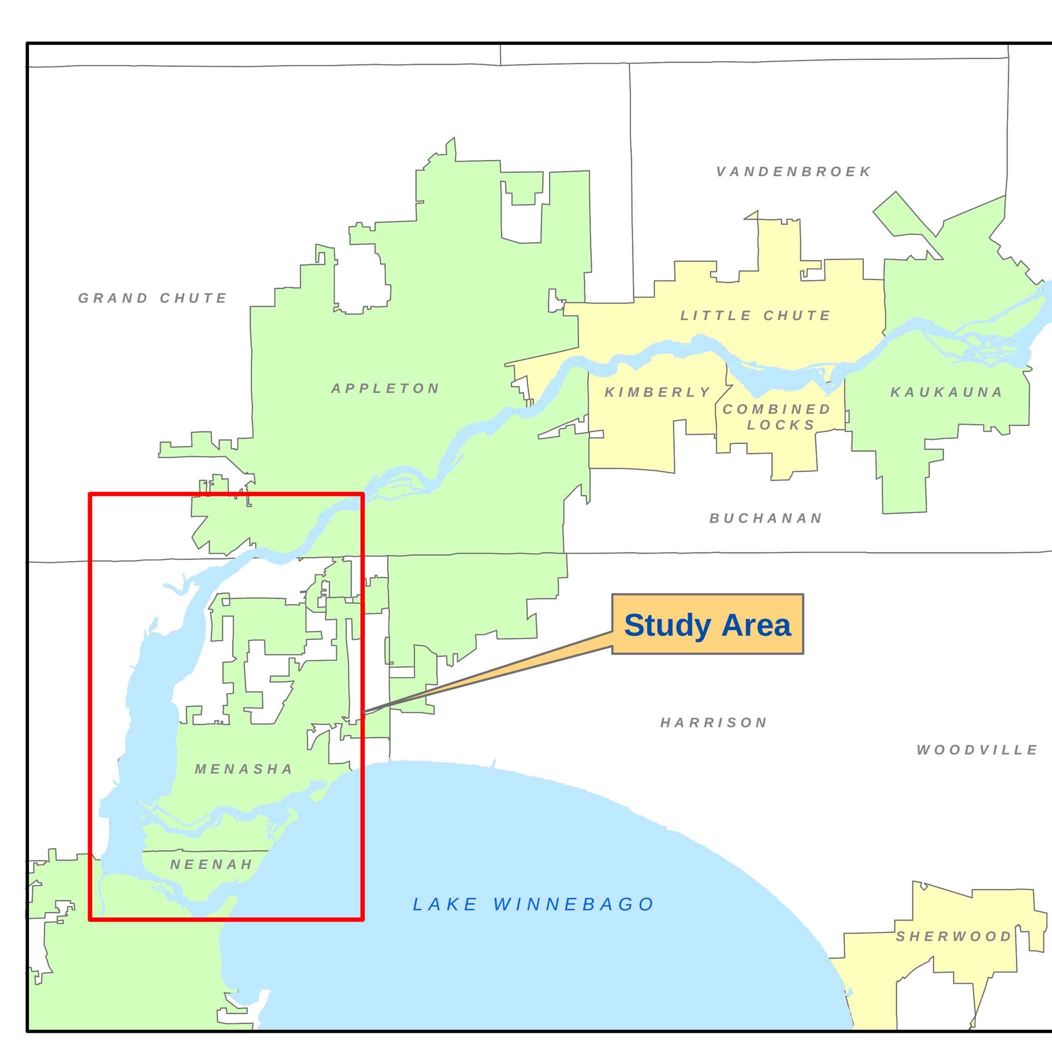




**MAP LEGEND**

- < 50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- > 50,000
- Lower Fox River
- Roads
- City
- Township
- Village

NOTES:
1. Basemap generated in ArcGIS, version 8.2.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcGIS Spatial Analyst, version 8.2.
3. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

Spatial Information:
Projection: Transverse Mercator
Parameters:
False Easting: 520000
False Northing: -4480000
Central Meridian: 0
Scale Factor: 0.9996
Latitude Of Origin: -90
Linear Unit: Meter (1)
Geographic Coordinate System:
Name: GCS_GRS_1980
Alias: Wisconsin Transverse Mercator (WTM), 1983 Datum
Angular Unit: Degree (0.017453292519943299)
Prime Meridian: Greenwich (0)
Geodetic Model:
Spheroid: GRS_1980
Horizontal Datum Name: D_GRS_1980
Ellipsoid Name: Geodetic Reference System 80
Semimajor Axis: 6378137
Semiminor Axis: 6356752.3141403561
Inverse Flattening: 298.25722210100002



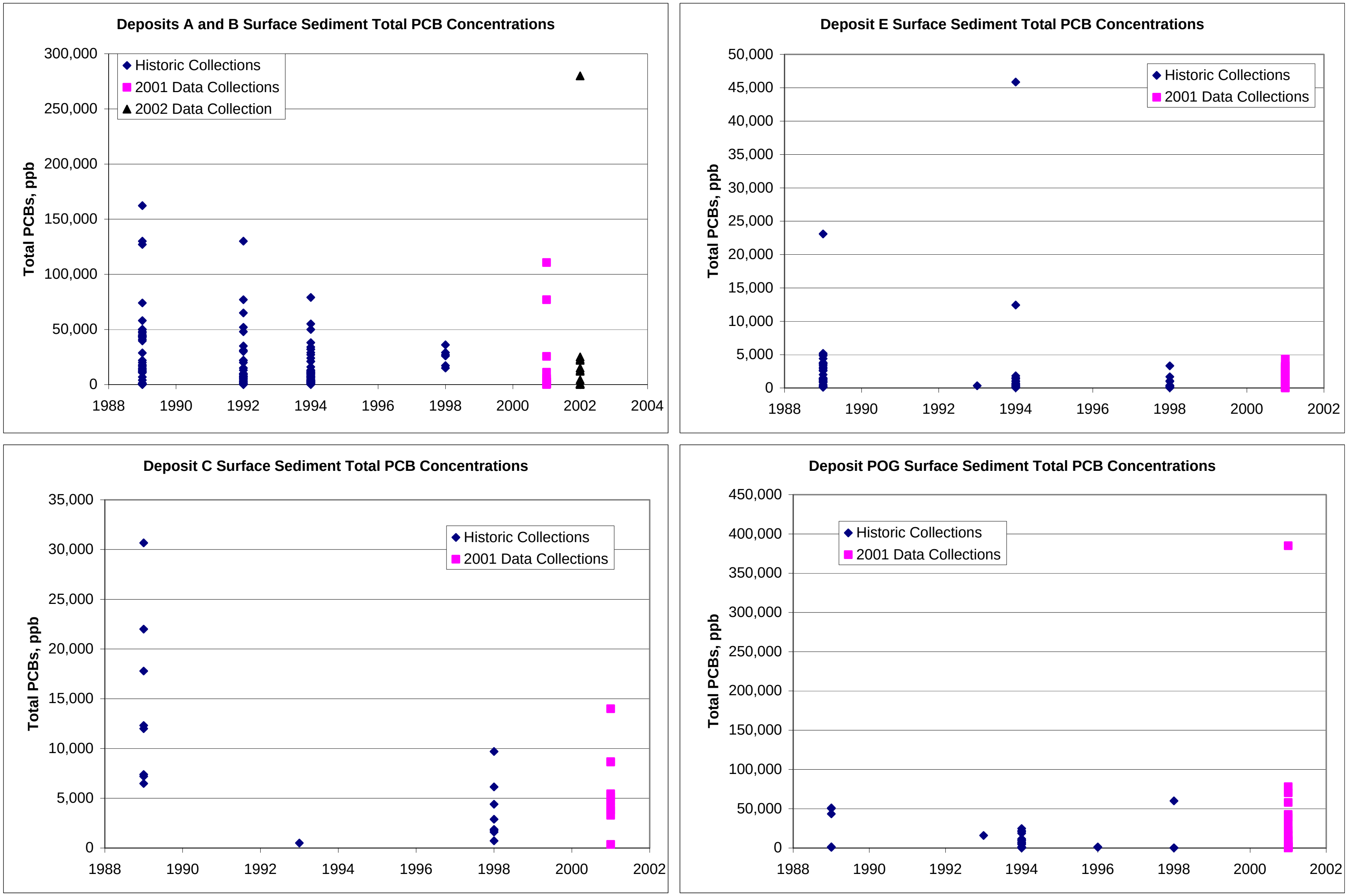

0 1500 3000 6000

1" = 1500 Feet

RETEC

| OPERABLE UNIT 1<br>Lower Fox River, Wisconsin (WISCN-15933-121) | | INTERPOLATED PCB DISTRIBUTION IN SEDIMENTS: LITTLE LAKE BUTTE DES MORTS (0-10 cm) | |
|---|---|---|---|
| DATE: 12/04/02 | DRWN: SCJ / SEA | MAP: PCB Reinterp.mxd | FIGURE: 11 |

## Figure 12  Surface Sediment Data Scatter Plots



# WHITE PAPER NO. 3 – FOX RIVER BATHYMETRIC SURVEY ANALYSIS

***Response to a Document by Limno-Tech, Inc.***

## REVIEW OF USEPA FIELDS ANALYSIS OF BED ELEVATION CHANGES IN THE LOWER FOX RIVER

January 2002


***This Document has been Prepared by***

United States Environmental Protection Agency

Region 5

Superfund Division FIELDS Team


**December 2002**

# White Paper No. 3 –
# Fox River Bathymetric Survey Analysis

## Abstract

This White Paper has been prepared in response to the Fox River Group's *Review of USEPA Fields Analysis of Bed Elevation Changes in the Lower Fox River* (LTI, 2001). The LTI Report suggested that the models used in the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* incorrectly uses the historic bathymetric data in the analysis of sediment bed dynamics. In response to that LTI report and the comments received, the FIELDS Team created a visual product based on the historic bathymetric surveys of the Lower Fox River to show changes in sediment elevation and volume between survey years. The results of the analysis showed sediment movement within and outside of the dredge areas.

12/05/02

# Fox River Bathymetric Survey Analysis

## Prepared by the FIELDS Team, U.S. EPA, Region 5, Superfund Division

## Introduction

The FIELDS Team was asked by the USEPA Fox River Remedial Project Manager to create a visual product of the U.S. Army Corps of Engineers' (COE) historic bathymetric surveys of the Lower Fox. The COE survey data encompassed the years 1995 through 2000 and were collected to support the COE's navigation dredging activities. The FIELDS Team interpolated (created estimates of) the COE bathymetric data and displayed these estimates on maps to show the changes in sediment elevation and sediment volume between survey years. The results demonstrate that sediment movement does occur, both within and outside of dredge areas. This document explains the methods, results, and conclusions found by the FIELDS Team. It replaces any previous USEPA maps and analyses of the Fox River bathymetric data. This report is intended to explain the methods of analysis on previous, as well as current, bathymetric survey data. Additionally, the report addresses specific questions from Limno-Tech, Inc about previous analyses. This analysis of the data pays particular attention to the method of estimation at unsampled locations, survey accuracy (+/-), and survey timing (whether the survey is pre- or post-dredge). Addressing these issues will help explain the limitations of the data and reduce uncertainty in the conclusions.

## Methods

Data sources

The data used for this document include the following:

1. Bathymetric Data: CD - "Lower Fox River USACE Hydrographic Survey Data 1995 - 2000", dated April 19, 2002. Limno-Tech, Inc.

2. Dredge Dates: USACE Dredging Report, Detroit District Website http://huron.lre.usace.army.mil/OandM/o&m.html

3. Bathymetric Survey Dates: Mike Stencil, U.S. Army Corps of Engineers, Kewaunee Area Office (Personal Communication)

The FIELDS Team received the bathymetric survey transect data as a text file (*.xyz) from the COE via Limno-Tech, Inc. The 10 data files covered the years 1995 to 2000. In 1995 and 1996, the survey data included only the area from the Fort Howard Turning Basin (FHTB) through the mouth of the Lower Fox River. For the years 1997-2000, the survey data extend farther upstream than the FHTB, up to the DePere Dam. Using Microsoft Excel, the files were combined so that each year was a separate, complete file. The data were reprojected from UTM Zone 16 to Wisconsin Transverse Mercator, NAD 27, using FME and converted to shapefiles in ArcView, a GIS software (see Figure 1).

The dredge dates are provided in Table 1. The bathymetric survey dates, locations, and whether or not the survey occurred after a dredge event are provided in Table 2.

<u>COE Bathymetric Survey Accuracy</u>
The COE states that the accuracy of their bathymetric surveys is ± 0.5 feet based on the use of a bar check before and after each bathymetric survey (Mike Stencil, Personal Communication). Bathymetric surveys conducted by the FIELDS Team also have found an accuracy better than ± 0.5 feet measured by comparing resamples of the same area. The authors of the LTI Review note that survey elevation changes within ± 1.4 feet are "within the range of uncertainty inherent in the survey equipment, survey methods, and data analysis techniques" (LTI Review, p. 1). Using ± 1.4 ft as an analytical control is overly conservative but was used, in this document, to compare the results obtained from assuming an accuracy of ± 0.5 feet with ± 1.4 feet (see Figure 2).

<u>Interpolation</u>
The purpose of interpolation is to create estimates at unsampled locations. The usefulness of interpolation is the ability to view point data (e.g., bathymetric survey data) as gridded (estimated) values that represent a surface. More significantly, interpolation allows one to estimate linear differences (e.g., 1996 sediment elevation estimates – 1995 sediment elevation estimates), area differences (e.g., proportion of surface area changes for a specific range), and volume differences (e.g., cubic yards of sediment lost or gained over time). The interpolation algorithms Inverse Distance Weighting (IDW) and Natural Neighbor were used to create estimates of sediment elevation at unsurveyed locations. These interpolation algorithms, like all other interpolation algorithms, "behave" better or worse, as regards to the original data, depending on the density and spacing of the original data, edge effects, and data clustering.

The COE bathymetric survey data were converted to shapefiles and were interpolated using the Inverse Distance Weighting (IDW) algorithm in ArcView's Spatial Analyst extension. The parameters used in the IDW algorithm were a power of 2, neighbor of 8, and a cell size of 5 meters (see Figure 3). These parameters were found to have the lowest cross validation residual (root-mean square error) using the FIELDS Tools (www.epa.gov/region5fields/). The lowest root-mean square error refers to the difference between interpolated values and the original values. Hence, interpolation parameters that give the lowest root-mean square error are often preferred. The data were not interpolated outside the lateral boundaries of the survey extent by the use of a polygon of the Fox River navigation boundary. The interpolated data were used to find differences in sediment elevation, sediment volume, and sediment surface area by various year combinations (e.g., 1996 – 1995) using ArcView's Map Calculator function. These differences were displayed in maps with dredged areas of Fox River designated by color-coded polygons (see Figure 4).

In order to assess potential bias in the interpolations, the bathymetric survey data for some of the years were interpolated using different powers and neighbors in the IDW algorithm. In addition, a different interpolator, Natural Neighbor, was also used to create estimates of sediment elevation. The results were used to compare the effects that different parameters and a different interpolation algorithm had on the results. The new results were compared year to year (see Figure 5). The new interpolations were also compared to the original interpolation (IDW, power of 2, neighbor of 8) and the difference between the two grids was calculated and displayed in a map format (see Figure 6).

<u>Outstanding Issues</u>
After acquiring the bathymetric survey dates from the COE Kewaunee office it became evident that some dredged areas were surveyed after the dredging event occurred. These areas were marked with asterisks on the maps (see Figure 7). Efforts are currently being made to determine if the data we used were, in fact, post-dredge, and how often this occurred in the data set (i.e., a more accurate Table 2).

## Results and Discussion

<u>Comparisons of Interpolation Algorithms</u>
Several comparisons of interpolation (estimation) algorithms and parameters were performed in order to evaluate their significance. These results are presented, by section, below.

1. Changes caused by Inverse Distance Weighting (IDW) parameters

    There appears to be little difference in the interpolated sediment elevation values for the maps of 1995-1996 and 1996-1997 when the IDW parameters are changed from a Power of 2, Neighbor of 8 to a Power of 6, Neighbor of 4 (see Figures 8a-d). This visual evaluation is confirmed from Figures 9a-d that show the numeric difference in interpolated sediment elevation values. These figures demonstrate that those areas with differences in interpolated sediment elevation occur along the edges of the study area for both accuracy values (± 0.5 and ± 1.4 feet ). This is expected as any interpolator performs less well at the spatial extent of the original data due to a lack of data values.

    There appears to be little difference in the interpolated sediment elevation values for the maps of 1995-1996 and 1996-1997 when the IDW parameters are changed from a Power of 2, Neighbor of 8 to a Power of 6, Neighbor of 12 (see Figures 10a-d). This visual evaluation is confirmed from Figures 11a-d that show the numeric difference in interpolated sediment elevation values. These figures demonstrate that those areas with differences in interpolated sediment elevation occur along the edges of the study area for both accuracy values (± 0.5 and ± 1.4 feet). This is expected as any interpolator performs less well at the spatial extent of the original data due to a lack of data values.

2. Changes caused by Interpolator

    Unlike the limited difference in the effect of differing IDW parameters, there are some differences in a visual evaluation of the interpolated sediment elevation values for the maps of 1995-1996 and 1996-1997 when IDW is compared to Natural Neighbor (NN).

(See Figures 12a-d.) However, as noted above, most of these differences occur at the edges of the study area. This finding is confirmed by Figures 13a-f. (These figures show the difference in interpolated sediment elevation values at two different accuracy values, ± 0.5 and ± 1.4 feet.)

Interpolated sediment elevation values (IDW, power of 2, neighbor of 8)

There were several sets of maps created from the interpolations of the bathymetric survey data. These results are presented, by section, below.

1. Comparisons of Accuracies (by year, including dredged and non-dredged areas)

   The "side-by-side" (see Figures 14a-f) maps show the differences in interpolated sediment elevation values using different accuracies by year. As demonstrated, quantitatively, in the "Volume estimates" section below, the use of an accuracy value of ± 0.5 feet (Figures 15a-f and 17a-f) versus ± 1.4 feet (Figures 16a-f and 18a-f) makes a very large difference. The maps show that there is a large decrease in areas considered to have significant change in sediment elevation when an accuracy value of ± 1.4 feet is used. All maps show that the changes in sediment elevation are spatially dispersed.

2. Comparisons (by year and accuracy, including dredged and non-dredged areas)

   Figures 15a-f and 16a-f provide a visualization of differences in interpolated sediment elevation values on a year-to-year basis for the entire study area. Many of the areas that show the largest decreases in interpolated sediment elevation values are in dredged areas. A year-to-year description is provided below:

   **1995-1996:** There were three areas dredged between the Fort Howard Turning Basin and the mouth of the river (see Figures 15a and 16a). Based on information received from the COE Kewaunee office, these areas are suspected to have been surveyed after the dredging occurred. This idea is supported by a visual inspection of the map itself. Transects 0+00 to 10+00 and 19+00 to 30+00 show negative change, while there is positive change in the Fort Howard Turning Basin. There is another section of the river (142+00 to 177+00) that also shows a positive change in sediment elevation. This area was not dredged in 1995 or 1996, but was dredged in 1994. There are also smaller areas of change, both positive and negative at the East River junction.

   Using an accuracy estimate of ± 0.5 feet shows that there is more change overall, and the above noted changes stand out a little less, because they are surrounded by areas of smaller positive or negative change in sediment elevation (see Figure 15a). For instance, at the East River junction, the area of negative change is much bigger. There is also positive change evident between 123+00 and 136+00 that was not shown on the previous map because it falls in the range of ± 0.5 feet. In addition, there are areas of positive change in the Fort Howard Turning Basin along the east bank of the river.

   **1996-1997:** In this map again there is a section of the river that was supposedly surveyed after it was dredged, and shows negative change (see Figures 15b and 16b). This is in the area north of the Fort Howard Turning Basin, transects 142+00 to 172+00. Another significant area of negative change is in the Fort Howard Turning Basin itself, the area dredged in 1996. Where there was positive change at this location in the 1995-1996 comparison, the comparison of 1996-1997 shows a negative change. There is also a small area of negative change between 85+00 and 97+00 that is consistent with a dredge event, but there is no USACE record of a dredge event in that specific area.

Using an accuracy estimate of ± 0.5 feet shows that the Fort Howard Turning Basin has a negative change on the east bank and positive change on the west bank (see Figure 15b). Using this uncertainty estimate shows more areas of change in the range of ± 0.5 feet, scattered about the river.

**1997-1998:** As in previous maps, the Fort Howard Turning Basin was suveyed in 1998 after dredging occurred (see Figures 15c and 16c). However, in this case, the change in sediment elevation is not as clear. The change is not as focused or consistent, but there is some obvious negative change. Also between 142+00 and 172+00 there is evidence of a positive change. This area was dredged in 1997.

Using an accuracy estimate of ± 0.5 feet shows that there is a much higher percentage of positive change in the ± 0.5 feet range, specifically from 0+00 to 33+00 and 142+00 to 177+00, with scattered change in between (see Figure 15c). The Fort Howard Turning Basin shows more negative change in the range of -1.5 to -0.5 feet.

**1998-1999:** Unlike previous comparisons, in this case there appears to be no areas that were dredged prior to the survey (see Figures 15d and 16d). This comparison also shows less change. There is a positive change in the Fort Howard Turning Basin, which was dredged in 1996 and 1998, and also positive change north of the turning basin, between 142+00 and 172+00. This area was dredged in 1997. There is also some smaller areas of positive and negative change at the East River junction.

Using an accuracy estimate of ± 0.5 feet shows that there is more positive change evident in the range of 0.5 to 1.5 feet especially in the Fort Howard Turning Basin, and near the mouth of the river (see Figure 15d). There is scattered areas of negative change in the range of -1.5 to -0.5 feet from the mouth of the river to 142+00, especially at the East River Junction.

**1999-2000:** In this comparison again, the area between 142+00 and 177+00 was dredged prior to the survey (see Figures 15e and 16e). While there is obvious change here, it is both positive and negative all in the same area. There are also small areas of negative change at the East River junction, and moderate areas of positive change in the Fort Howard Turning Basin. In addition, there is some smaller spots of positive change near the mouth of the river.

Using an accuracy estimate of ± 0.5 feet shows more positive change of 0.5 to 1.5 ft near the mouth of the river, in the turning basin, and between 123+00 and the turning basin (see Figure 15e). There is also some scattered negative change at the East River junction and throughout the river.

**1995-2000:** Figures 15f and 16f show the changes in interpolated sediment elevation values from 1995 through 2000. Both within and outside of dredge areas, there is significant changes in interpolated sediment elevation values. The majority of the dredge areas show declines in interpolated sediment elevation values, while those areas outside of historic dredge areas show increases.

3. Comparisons (by year and accuracy, in non-dredged areas only)

   These maps, Figures 17a-f and 18a-f, show the changes in elevation on a year-to-year basis using accuracy values of ± 0.5 feet and ± 1.4 feet, respectively. The maps demonstrate a consistent change (both increases and decreases) in sediment elevation across from the former Fort James plant (now Georgia Pacific) over time. (See the "elbow" on the right-hand side of the maps.) This is likely due to ship traffic in the area. Most significantly, the comparison of 1995 to 2000 shows the cumulative changes in sediment elevation over this five-year period (see Figures 17f and 18f). The majority of areas showing changes in interpolated sediment elevation are positive values.

**Volume estimates**

Table 3 displays the estimates of sediment volume changes in cubic yards (cu. yd) by one-year increments, save for the last entry in the table which shows the change between 1995 and 2000, for areas that were not dredged. The values in the two columns with the header "± 0.5 ft" and "± 1.4 ft" provide estimates of the gain and loss of sediment volumes by year. The difference between these two columns is the accuracy value used. The first column uses an accuracy value of ± 0.5 feet (ft). Hence any change in sediment elevation, for interpolated values, that was less than or equal to 0.5 feet and was greater than -0.5 feet, was not included in the calculation of the volume of sediment. The other column uses an accuracy value of ± 1.4 feet (ft), a value suggested by the authors of the LTI Review. As with the ± 0.5 feet accuracy value, any change in sediment elevation, for interpolated values, that was within the interval ± 1.4 feet was not included in the calculation of the volume of sediment.

The table shows, for the accuracy value ± 0.5 feet, that there were fairly consistent volume changes for the year-by-year comparisons except for the years 1998 to 1999. (Note both the volume values as well as the ratios. The latter value is created by dividing the volume gain by the volume loss.) In general, there were more instances of sediment volume gain than loss. This is expected as it confirms the COE need to perform navigational dredging in order to remove areas of sediment elevation. Although the use of the ± 1.4 feet accuracy value shows more instances of sediment volume loss, the cumulative change between 1995 and 2000 shows a gain in sediment volume.

The inclusion of dredge areas in the estimation of sediment volume changes shows, as expected, that the volume estimates in Table 4 are much larger than those in Table 3. This finding demonstrates that a significant proportion of the changed in sediment volumes from one year to the next is due to dredging activities conducted by the COE in the Fox River. As in Table 3, there was one more instance of sediment volume gain greater than loss when the accuracy value ± 0.5 feet was used. Using an accuracy value of ± 1.4 feet shows that there was one more instance of sediment volume loss greater than gain. However, for the period 1995 through 2000, there appears to be a net increase in sediment volume, regardless of the accuracy value used.

**Surface area estimates**

Tables 5 and 6 provide estimates of the percent of the Fox River study area with significant changes in sediment elevation in year-to-year comparisons. In those portions of the Fox River study area not dredged (see Table 3) approximately 12 to 40 percent of the surface area of the Fox River study area undergoes elevation changes greater than 0.5 feet and less than or equal to -0.5 feet on a year-to-year basis. If an accuracy value of ± 1.4 feet is used, these percent surface area values decrease to 2.5 to 14 percent. If dredge areas are included in the estimation of percent surface area with significant changes in sediment elevation, these values increase (see Table 6). For an accuracy value of ± 0.5 feet, the percentage of the study area with elevation changes ranges from 13 to 40. Using an accuracy value of ± 1.4 feet, these values decrease: 3.5 to 15 percent. As expected, both tables show that there is proportionately more areas with increases in sediment elevation than areas with decreases (see years 1995 to 2000 in Tables 5 and 6).

**Maximum change and range of values**

Tables 7 and 8 give estimates of the maximum positive and negative change in interpolated sediment elevation values, in feet, for each year-to-year comparison. The tables also show the estimated percentage of values falling within 5 ranges: -0.5 to 0.5 feet, -1.5 to -0.5 feet, < -1.5 feet, 0.5 to 1.5 feet, and > 1.5 feet. As demonstrated in the above figures, a large proportion of estimated sediment elevation changes are within the range of -0.5 to 0.5 feet. However, 7-10% of all estimated sediment elevation changes are greater than 1.5 feet and less than -1.5 feet (see Table 7, non-dredged areas excluded). This range of percentage values increases to 13-15% when dredged areas are included (see Table 8).

## Conclusions

The Lower Fox River sediment is part of a dynamic system that warrants close monitoring and in some areas requires repeated dredging over time. The FIELDS Team's maps and analyses of the COE bathymetric survey data show that both erosional and depositional factors are involved in the Fox River sediment system. The remaining questions relate only to the magnitude of those changes. Although the bathymetric surveys performed by the COE cannot be used quantitatively to determine the absolute extent of sediment movement due to dredging activities, they are an indication of a dynamic system that may warrant more detailed analysis. And, as only the navigational channel was surveyed, one cannot extrapolate to areas of the Fox River outside of the navigational bathymetric survey extent. Such a limitation may require that an investigation and possible monitoring for changes in sediment is prudent.

Although sources of this sediment cannot be definitively determined by a bathymetric survey, likely sources of the sediment are runoff (lateral sources), upstream sources, and saltation of existing river sediment. The important point is that, since sediment is being both eroded and deposited in the Fox River system, reasonable care should be taken to avoid having contaminated sediments move into areas currently below the risk level and to avoid having surface sediments with low concentrations of contamination move to expose underlying sediments with higher concentration contamination. Even if net scour is significantly lower than net deposition the preferential movement of certain sediments could greatly increase the overall surface concentration of PCBs, and increase the cost of remediating contaminated sediments as they spread.

## References

Limno-Tech, Inc., (LTI), Review of USEPA FIELDS Analysis of Bed Elevation Changes in the Lower Fox River. January, 2002. Referred to in the document as “LTI Review”.

## Appendix

**Table 1.** Dredge dates.

**Table 2.** Bathymetric Survey and Dredging Dates.

**Table 3.** Volume estimates (dredged areas excluded).

**Table 4.** Volume estimates (dredge and non-dredge areas).

**Table 5.** Surface area estimates (dredged areas excluded).

**Table 6.** Surface area estimates (dredge and non-dredge areas).

**Table 7.** Maximum Change and Range of Values (dredged areas excluded).

**Table 8.** Maximum Change and Range of Values (dredge and non-dredge areas).

**Table 1**
Dredge dates

| Dredge Year | Dredge Dates |
|---|---|
| 1995 | August 22 – November 13 |
| 1996 | August 20 – November 22 |
| 1997 | September 15 – December 9 |
| 1998 | September 1 – December 2 |
| 1999 | July 2 – August 9 |
| 2000 | August 22 – December 22 |

The dredging dates in the Lower Fox River were provided by COE Kewaunee office.

**Table 2**
Bathymetric Survey and Dredging Dates

| Survey Transects | Survey dates | Pre- or Post-dredge |
|---|---|---|
| 0+00 TO 23+00 | 22JUN95 | |
| 24+00 TO 85+00 | 27JUN95 | |
| 86+00 TO 96+00 | 28JUN95 | |
| 97+00 TO 122+00 | 29JUN95 | |
| 123+00 TO 176+00 | 05JUL95 | |
| 177+00 TO 190+00 | 12JUL95 | |
| 0+00 TO 20+00 | 25JUN96 | |
| 21+00 TO 55+00 | 26JUN96 | |
| 56+00 TO 82+00 | 27JUN96 | |
| 83+00 TO 145+00 | 01JUL96 | |
| 146+00 TO 187+84 | 02JUL96 | |
| 176+85 TO 187+84 | 11SEP96 | AFTER DREDGE |
| 0+00 TO 10+00 | 14NOV96 | AFTER DREDGE |
| 19+00 TO 33+00 | 26NOV96 | AFTER DREDGE |
| 0+00 TO 69+00 | 09JUL97 | |
| 70+00 TO 114+00 | 14JUL97 | |
| 115+00 TO 140+00 | 15JUL97 | |
| 140+37 TO 209+00 | 22JUL97 | |
| 142+00 TO 172+00 | 11DEC97 | AFTER DREDGE |
| 0+00 | 01JUL98 | |
| 5+00 TO 45+00 | 01JUL98 | |
| 46+00 TO 109+00 | 08JUL98 | |
| 110+00 TO 162+00 | 13JUL98 | |
| 163+00 TO 176+58 | 14JUL98 | |
| 187+84 TO 215+00 | 14JUL98 | |
| 1+00 TO 4+00 | 21JUL98 | |
| 177+85 TO 188+00 | 09DEC98 | AFTER DREDGE |
| 0+00 TO 35+00 | 29JUN99 | |
| 36+00 TO 105+00 | 02AUG99 | |
| 106+00 TO 155+00 | 03AUG99 | |
| 156+00 TO 210+00 | 05AUG99 | |
| 0+00 TO 65+00 | 21JUN00 | |
| 86+00 TO 142+00 | 22JUN00 | |
| 178+00 TO 190+00 | 29JUN00 | |
| 176+00 TO 177+00 | 10JUL00 | |
| 66+00 TO 85+00 | 10JUL00 | |
| 142+00 TO 176+55 | 05OCT00 | AFTER DREDGE |

**Table 3**
Volume estimates (dredged areas excluded)

| Years | Volume Change | ± 0.5 ft[#] (cu. yd) | Ratio (Gain/Loss)[*] | ± 1.4 ft[#] (cu. yd) | Ratio (Gain/Loss)[*] |
|---|---|---|---|---|---|
| 95 - 96 | Gain | 32,335 | 1.28 | 11,698 | 0.75 |
| | Loss | 25,233 | | 15,521 | |
| 96 - 97 | Gain | 34,439 | 1.24 | 18,925 | 1.18 |
| | Loss | 27,688 | | 16,087 | |
| 97 - 98 | Gain | 46,408 | 2.50 | 25,868 | 3.45 |
| | Loss | 18,591 | | 7,503 | |
| 98 - 99 | Gain | 27,633 | 0.53 | 12,316 | 0.41 |
| | Loss | 51,833 | | 30,419 | |
| 99 - 00 | Gain | 39,562 | 1.15 | 17,868 | 0.83 |
| | Loss | 34,536 | | 21,590 | |
| 95 - 00 | Gain | 92,035 | 2.48 | 62,979 | 2.64 |
| | Loss | 37,075 | | 23,899 | |

[#] The values in these two columns are cubic yards (cu. yd) of sediment. The difference between these two columns is the accuracy value used. The first column uses an accuracy value of ± 0.5 feet (ft). Hence any change in sediment elevation, for interpolated values, that was less than or equal to 0.5 feet and was greater than -0.5 feet, was not included in the calculation of the volume of sediment. The other column uses an accuracy value of ± 1.4 feet (ft), a value suggested by the authors of the LTI Review. As with the ± 0.5 feet accuracy value, any change in sediment elevation, for interpolated values, that was within the interval ± 1.4 feet was not included in the calculation of the volume of sediment.

[*] The values in these two columns were created by dividing the volume gain by the volume loss for a particular year-to-year change. These values provide a simple means to compare the year-to-year values to each other.

**Table 4**
Volume estimates (dredge and non-dredge areas)

| Years | Volume Change | ± 0.5 ft# (cu. yd) | Ratio (Gain/Loss)* | ± 1.4 ft# (cu. yd) | Ratio (Gain/Loss)* |
|---|---|---|---|---|---|
| 95 - 96 | Gain | 107,870 | 0.94 | 59,859 | 0.69 |
| | Loss | 115,205 | | 86,193 | |
| 96 - 97 | Gain | 76,907 | 0.36 | 34,011 | 0.20 |
| | Loss | 210,459 | | 173,727 | |
| 97 - 98 | Gain | 170,945 | 2.88 | 106,662 | 3.25 |
| | Loss | 59,335 | | 32,838 | |
| 98 - 99 | Gain | 131,862 | 1.38 | 71,546 | 1.23 |
| | Loss | 95,449 | | 57,937 | |
| 99 - 00 | Gain | 127,182 | 1.10 | 68,134 | 0.89 |
| | Loss | 115,400 | | 76,897 | |
| 95 - 00 | Gain | 198,749 | 1.49 | 130,203 | 1.44 |
| | Loss | 133,312 | | 90,278 | |

# The values in these two columns are cubic yards (cu. yd) of sediment. The difference between these two columns is the accuracy value used. The first column uses an accuracy value of ± 0.5 feet (ft). Hence any change in sediment elevation, for interpolated values, that was less than or equal to 0.5 feet and was greater than -0.5 feet, was not included in the calculation of the volume of sediment. The other column uses an accuracy value of ± 1.4 feet (ft), a value suggested by the authors of the LTI Review. As with the ± 0.5 feet accuracy value, any change in sediment elevation, for interpolated values, that was within the interval ± 1.4 feet was not included in the calculation of the volume of sediment.

* The values in these two columns were created by dividing the volume gain by the volume loss for a particular year-to-year change. These values provide a simple means to compare the year-to-year values to each other.

**Table 5**
Surface area estimates (dredged areas excluded)

| Years | Elevation Change | ± 0.5 ft # (cu. yd) | ± 1.4 ft # (cu. yd) |
|---|---|---|---|
| 95 - 96 | Increase | 20.8% | 3.6% |
| | Decrease | 14.4% | 4.4% |
| 96 - 97 | Increase | 21.6% | 4.8% |
| | Decrease | 14.2% | 4.7% |
| 97 - 98 | Increase | 24.5% | 7.4% |
| | Decrease | 12.1% | 2.5% |
| 98 - 99 | Increase | 16.0% | 3.6% |
| | Decrease | 24.3% | 7.8% |
| 99 - 00 | Increase | 16.5% | 3.9% |
| | Decrease | 39.1% | 14.3% |
| 95 - 00 | Increase | 40.9% | 17.8% |
| | Decrease | 17.5% | 6.9% |

# The values in these two columns are cubic yards (cu. yd) of sediment. The difference between these two columns is the accuracy value used. The first column uses an accuracy value of ± 0.5 feet (ft). Hence any change in sediment elevation, for interpolated values, that was less than or equal to 0.5 feet and was greater than -0.5 feet, was not included in the calculation of the volume of sediment. The other column uses an accuracy value of ± 1.4 feet (ft), a value suggested by the authors of the LTI Review. As with the ± 0.5 feet accuracy value, any change in sediment elevation, for interpolated values, that was within the interval ± 1.4 feet was not included in the calculation of the volume of sediment.

**Table 6**
Surface area estimates (dredge and non-dredge areas)

| Years | Elevation Change | ± 0.5 ft # (cu. yd) | ± 1.4 ft # (cu. yd) |
|---|---|---|---|
| 95 - 96 | Increase | 23.0% | 6.9% |
| | Decrease | 18.1% | 8.0% |
| 96 - 97 | Increase | 19.0% | 3.5% |
| | Decrease | 27.2% | 15.3% |
| 97 - 98 | Increase | 40.0% | 11.1% |
| | Decrease | 13.0% | 3.9% |
| 98 - 99 | Increase | 27.9% | 8.6% |
| | Decrease | 18.5% | 6.2% |
| 99 - 00 | Increase | 28.1% | 9.0% |
| | Decrease | 20.9% | 7.8% |
| 95 - 00 | Increase | 38.9% | 16.0% |
| | Decrease | 24.1% | 9.9% |

# The values in these two columns are cubic yards (cu. yd) of sediment. The difference between these two columns is the accuracy value used. The first column uses an accuracy value of ± 0.5 feet (ft). Hence any change in sediment elevation, for interpolated values, that was less than or equal to 0.5 feet and was greater than -0.5 feet, was not included in the calculation of the volume of sediment. The other column uses an accuracy value of ± 1.4 feet (ft), a value suggested by the authors of the LTI Review. As with the ± 0.5 feet accuracy value, any change in sediment elevation, for interpolated values, that was within the interval ± 1.4 feet was not included in the calculation of the volume of sediment.

**Table 7**
Maximum Change and Range of Values (dredged areas excluded)

| Years | Maximum Change (ft) | | % of values in range of -0.5 to 0.5 ft | % of values in Negative Range | | % of values in Positive Range | |
|---|---|---|---|---|---|---|---|
| | Positive | Negative | | -1.5 to -0.5 ft | < -1.5 ft | 0.5 to 1.5 ft | > 1.5 ft |
| 1995 - 1996 | 8.5 | -9.7 | 65 % | 10 % | 4 % | 18 % | 3 % |
| 1996 - 1997 | 9.0 | -5.9 | 64 % | 10 % | 4 % | 18 % | 4 % |
| 1997 - 1998 | 9.5 | -5.7 | 63 % | 10 % | 2 % | 18 % | 7 % |
| 1998 - 1999 | 6.8 | -10.4 | 60 % | 17 % | 7 % | 13 % | 3 % |
| 1999 - 2000 | 7.6 | -13.9 | 59 % | 12 % | 5 % | 19 % | 5 % |
| 1995 - 2000 | 8.4 | -13.2 | 42 % | 11 % | 6 % | 25% | 16% |

**Table 8**
Maximum Change and Range of Values (dredge and non-dredge areas)

| Years | Maximum Change (ft) | | % of values in range of -0.5 to 0.5 ft | % of values in Negative Range | | % of values in Positive Range | |
|---|---|---|---|---|---|---|---|
| | Positive | Negative | | -1.5 to -0.5 ft | < -1.5 ft | 0.5 to 1.5 ft | > 1.5 ft |
| 1995 - 1996 | 8.5 | -12.7 | 59 % | 10 % | 8 % | 17 % | 6 % |
| 1996 - 1997 | 11.5 | -19.8 | 53 % | 13 % | 6 % | 20 % | 8 % |
| 1997 - 1998 | 13.1 | -10.8 | 52 % | 10 % | 3 % | 25 % | 10 % |
| 1998 - 1999 | 11.2 | -12.2 | 53 % | 13 % | 6 % | 20 % | 8 % |
| 1999 - 2000 | 9.2 | -13.8 | 51 % | 14 % | 7 % | 20 % | 8 % |
| 1995 - 2000 | 8.5 | -13.2 | 38 % | 15 % | 9 % | 23 % | 15 % |

# Figures for the “Fox River Bathymetric Survey Analysis” Report

**Prepared by**

**the FIELDS Team**
**U.S. EPA, Region 5, Superfund Division**

**Figure 1**

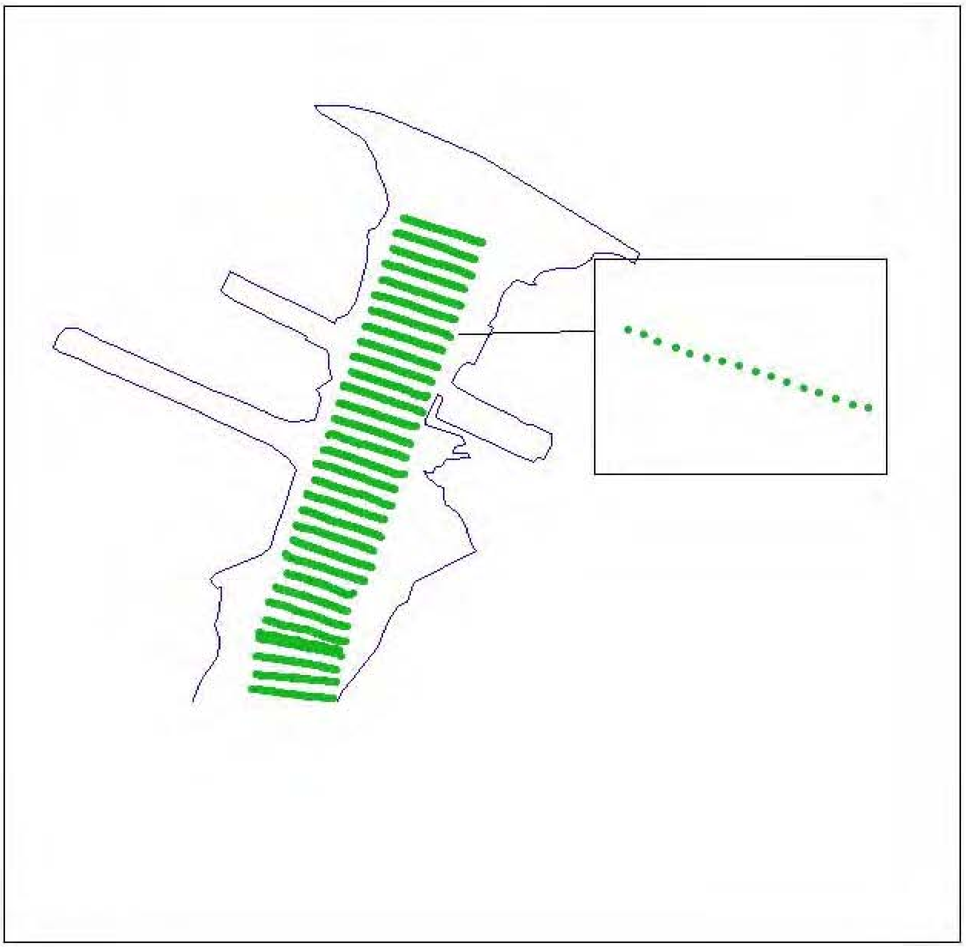


**Figure 2**

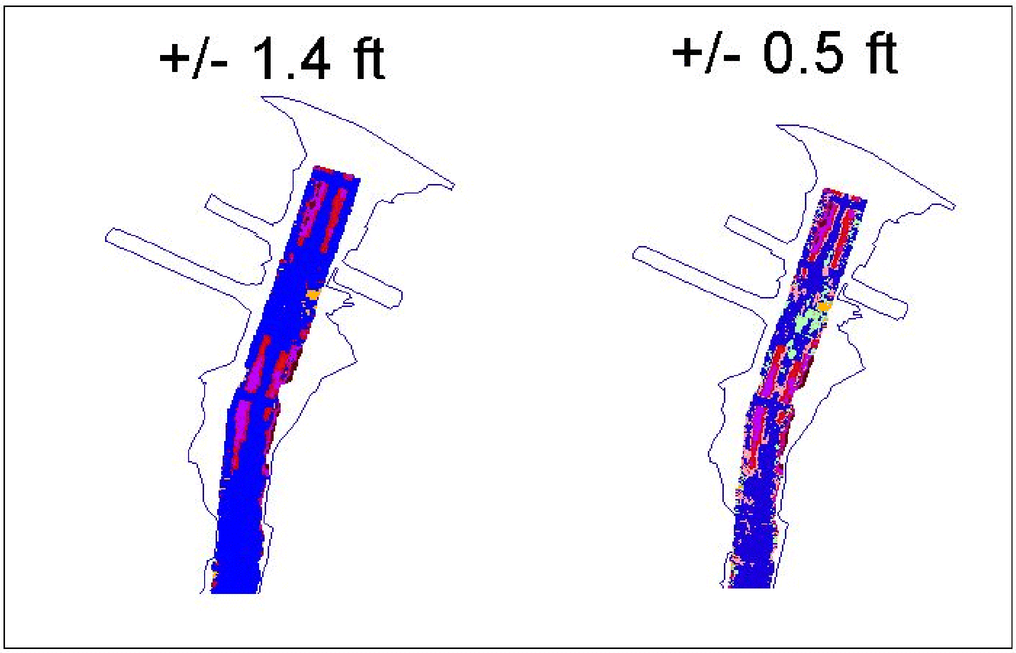


**Figure 3**

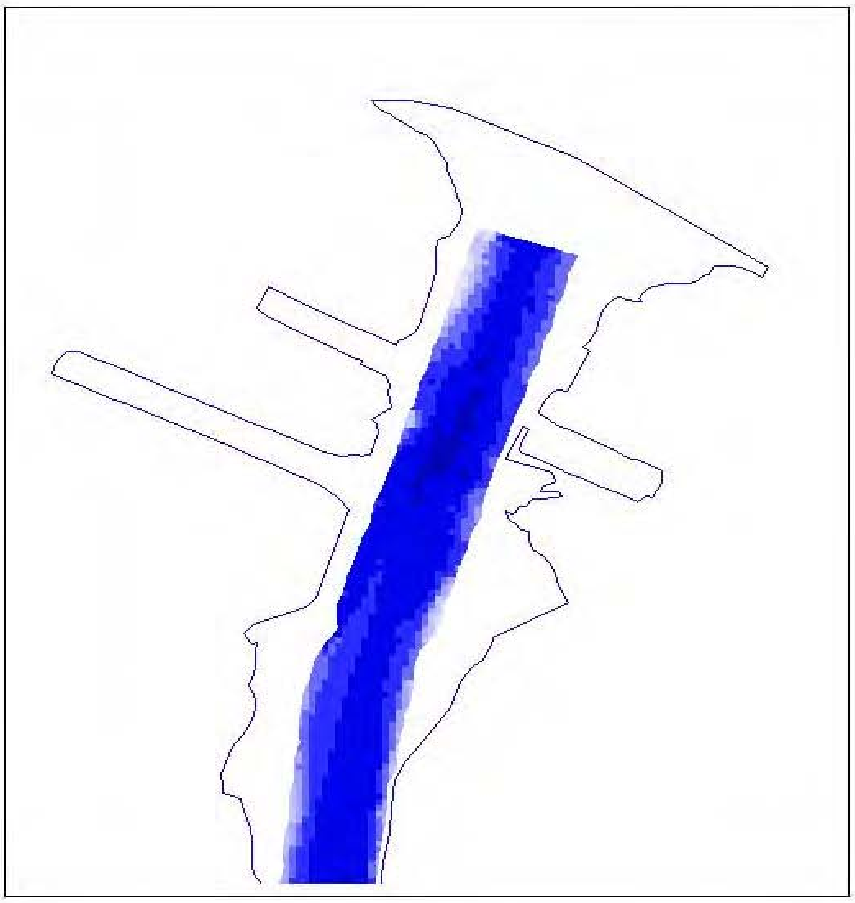


**Figure 4**

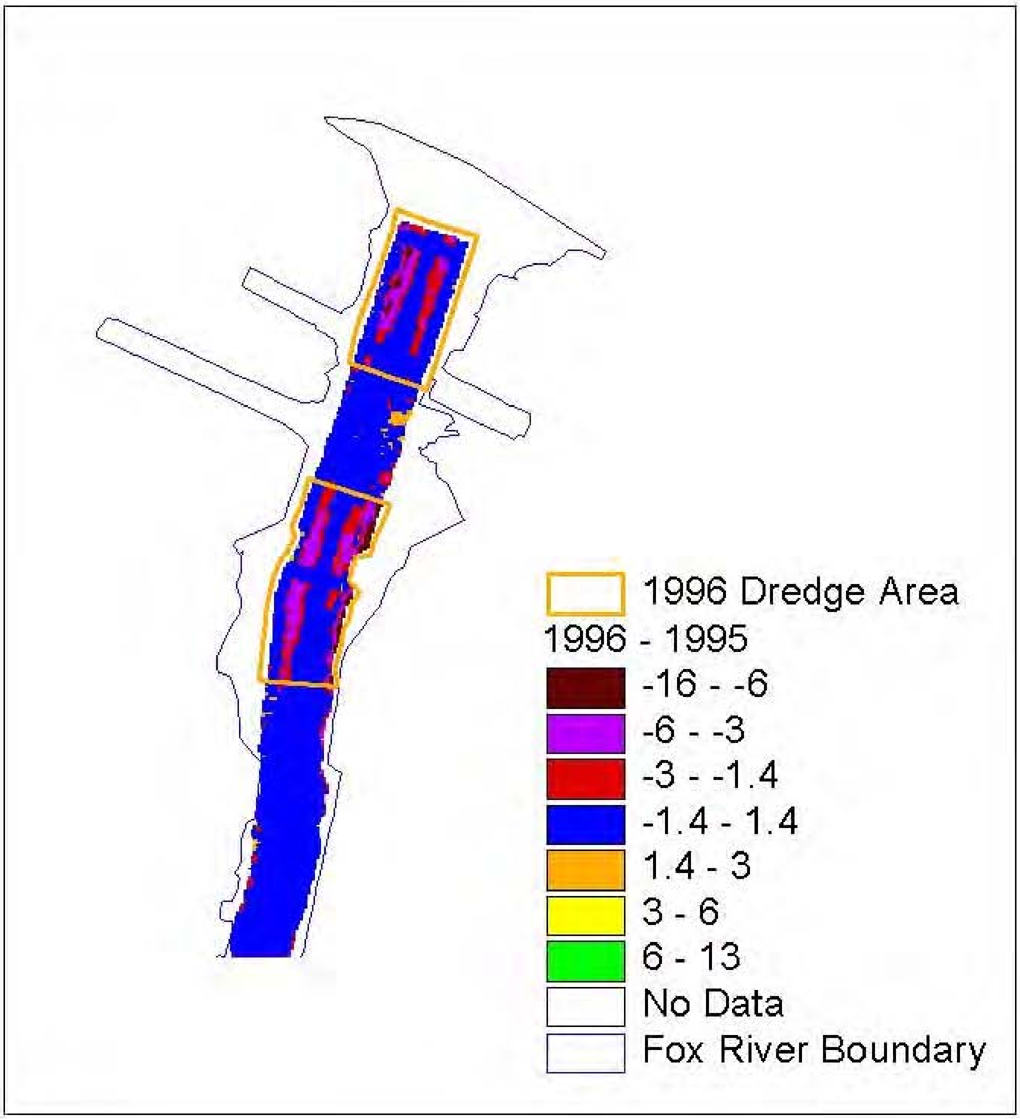

1996 Dredge Area
1996 - 1995
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary

**Figure 5**

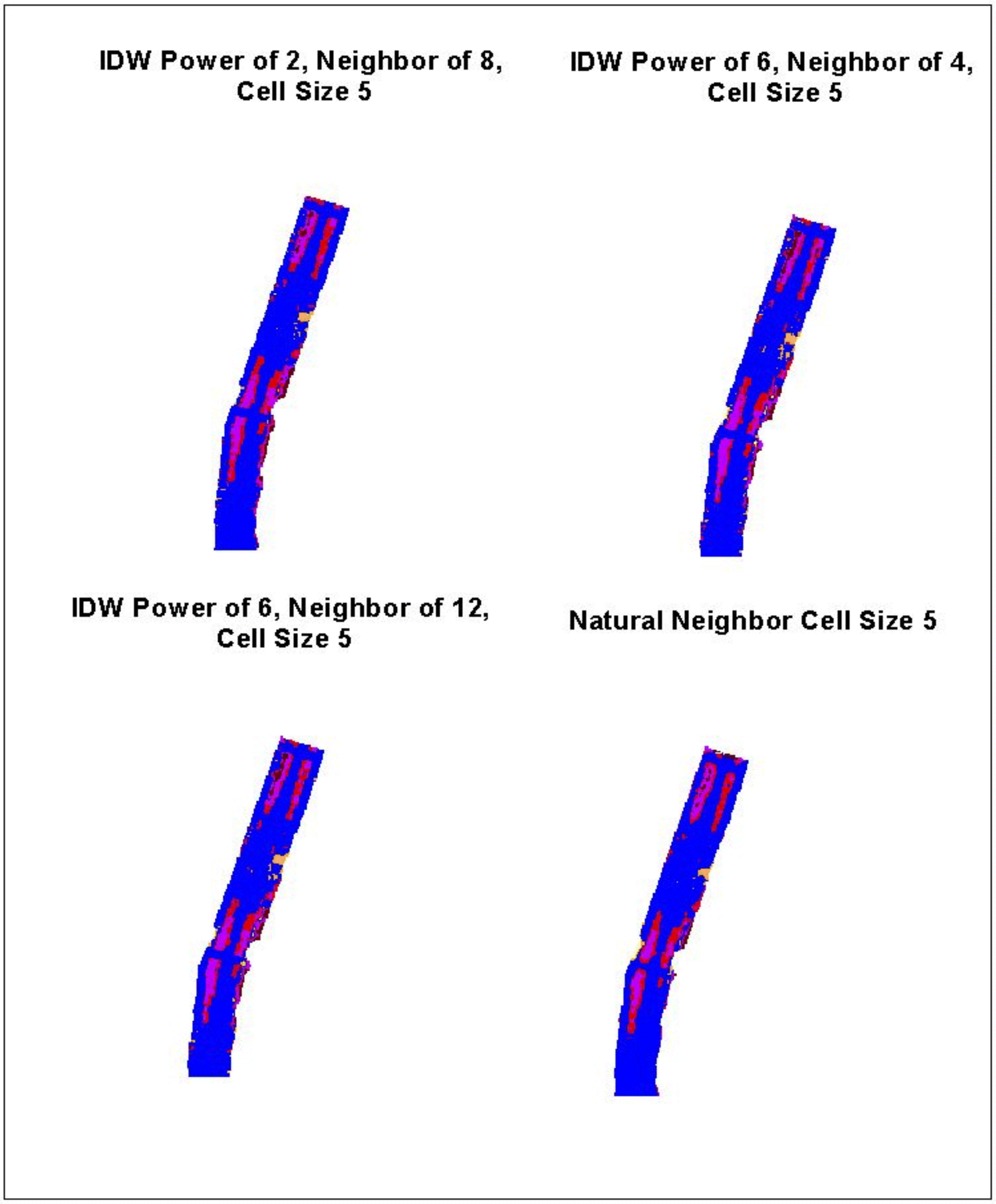

IDW Power of 2, Neighbor of 8, Cell Size 5
IDW Power of 6, Neighbor of 4, Cell Size 5
IDW Power of 6, Neighbor of 12, Cell Size 5
Natural Neighbor Cell Size 5

**Figure 6**

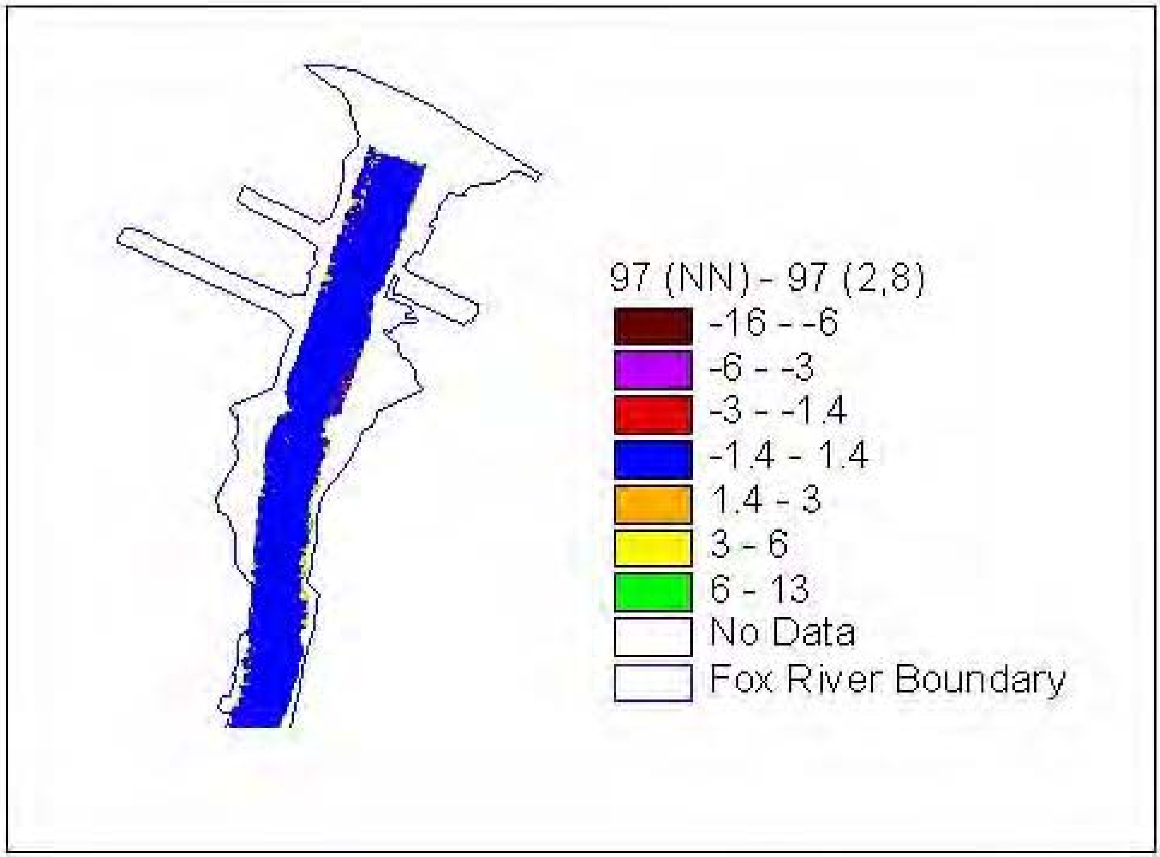
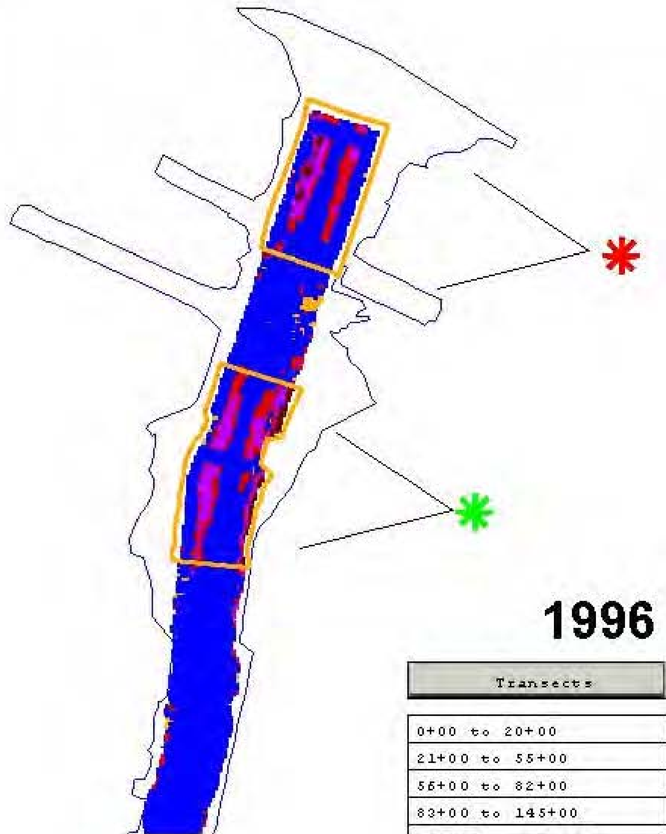

97 (NN) - 97 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary

**Figure 7**



## 1996 Data

| | Transects | Survey Date |
|---|---|---|
| | 0+00 to 20+00 | 6/25/96 |
| | 21+00 to 55+00 | 6/26/96 |
| | 56+00 to 82+00 | 6/27/96 |
| | 83+00 to 145+00 | 7/01/96 |
| | 146+00 to 187+84 | 7/02/96 |
| | 176+85 to 187+84 | 9/11/96 |
| * (red) | 0+00 to 10+00 | 11/14/96 |
| * (green) | 19+00 to 33+00 | 11/24/96 |

**Figure 8a**

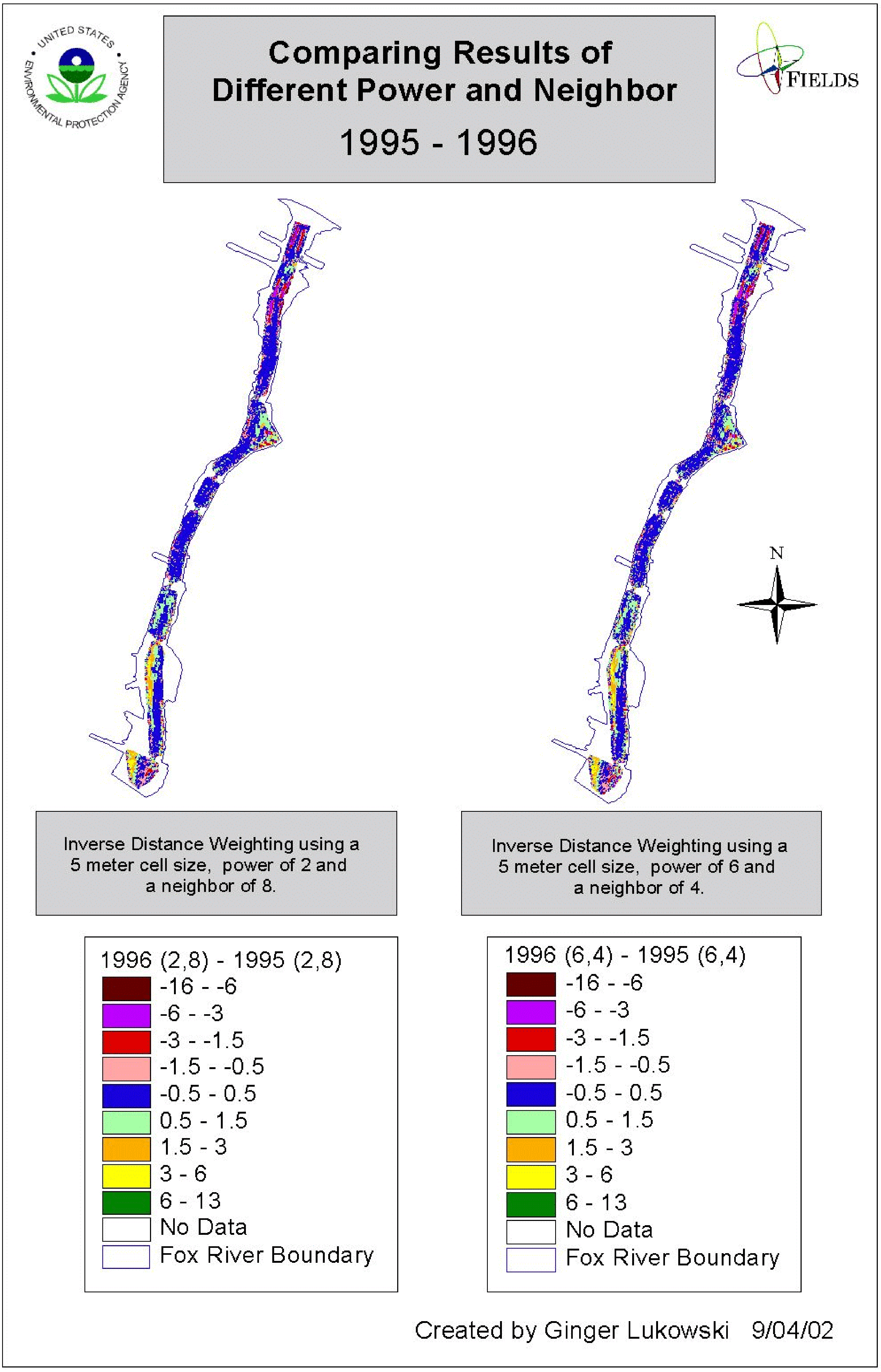
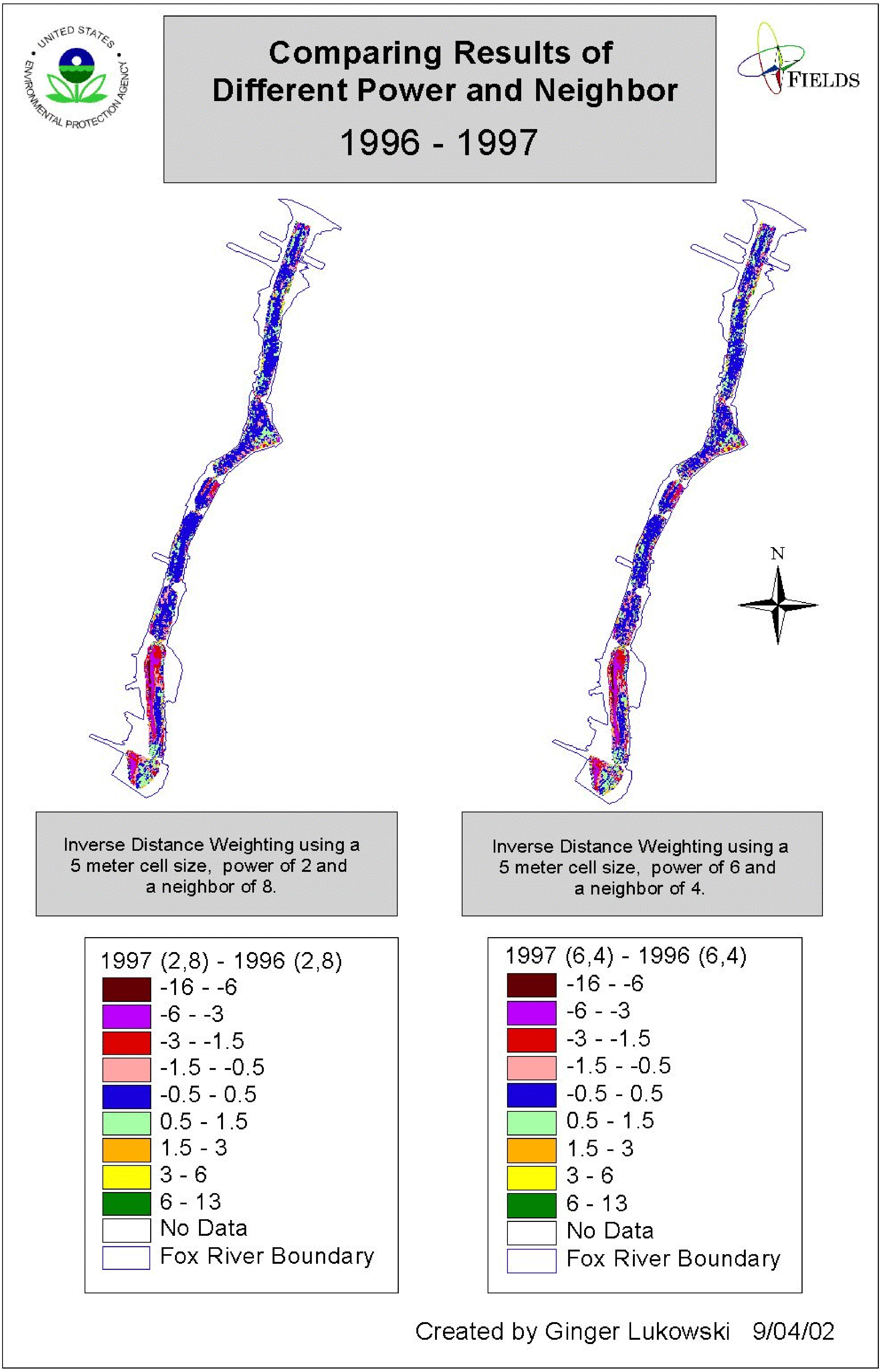
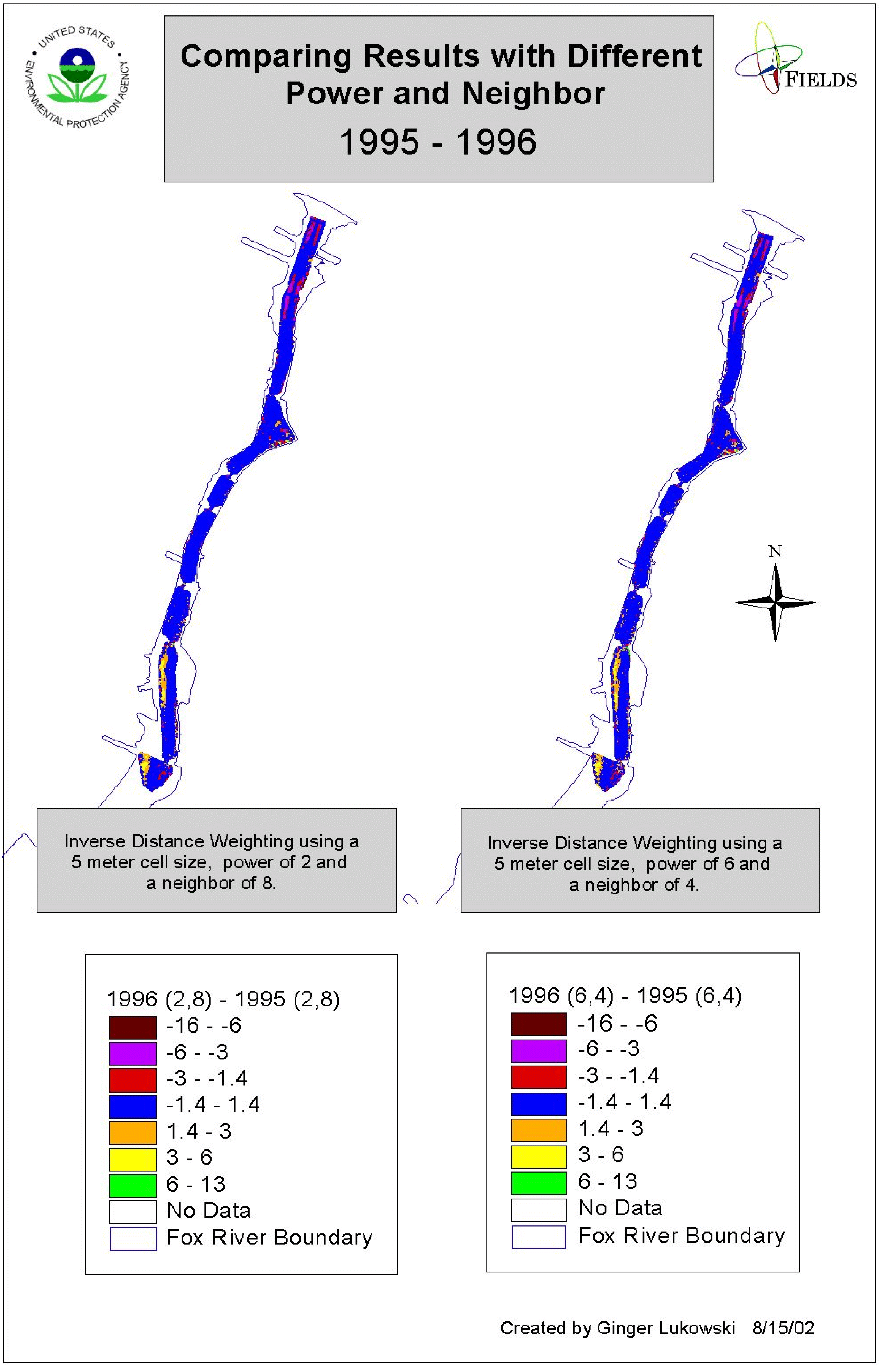

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Comparing Results of
Different Power and Neighbor
1995 - 1996
FIELDS
N
Inverse Distance Weighting using a
5 meter cell size, power of 2 and
a neighbor of 8.
Inverse Distance Weighting using a
5 meter cell size, power of 6 and
a neighbor of 4.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (6,4) - 1995 (6,4)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 8b**



Comparing Results of
Different Power and Neighbor
1996 - 1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 4.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (6,4) - 1996 (6,4)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 8c**



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Comparing Results with Different Power and Neighbor
1995 - 1996
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 4.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (6,4) - 1995 (6,4)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 8/15/02

**Figure 8d**

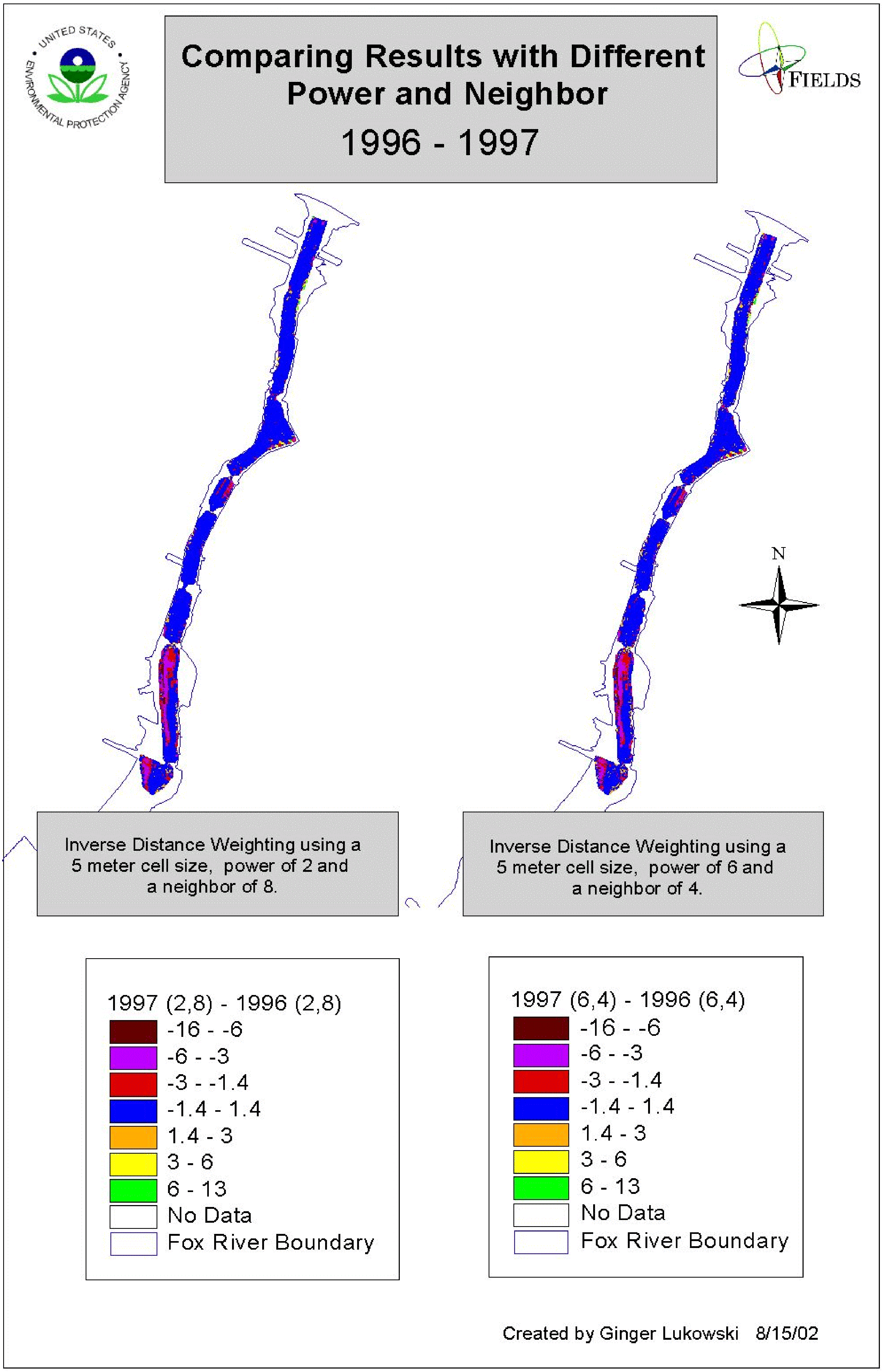

Comparing Results with Different Power and Neighbor
1996 - 1997
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 4.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (6,4) - 1996 (6,4)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 8/15/02

**Figure 9a**

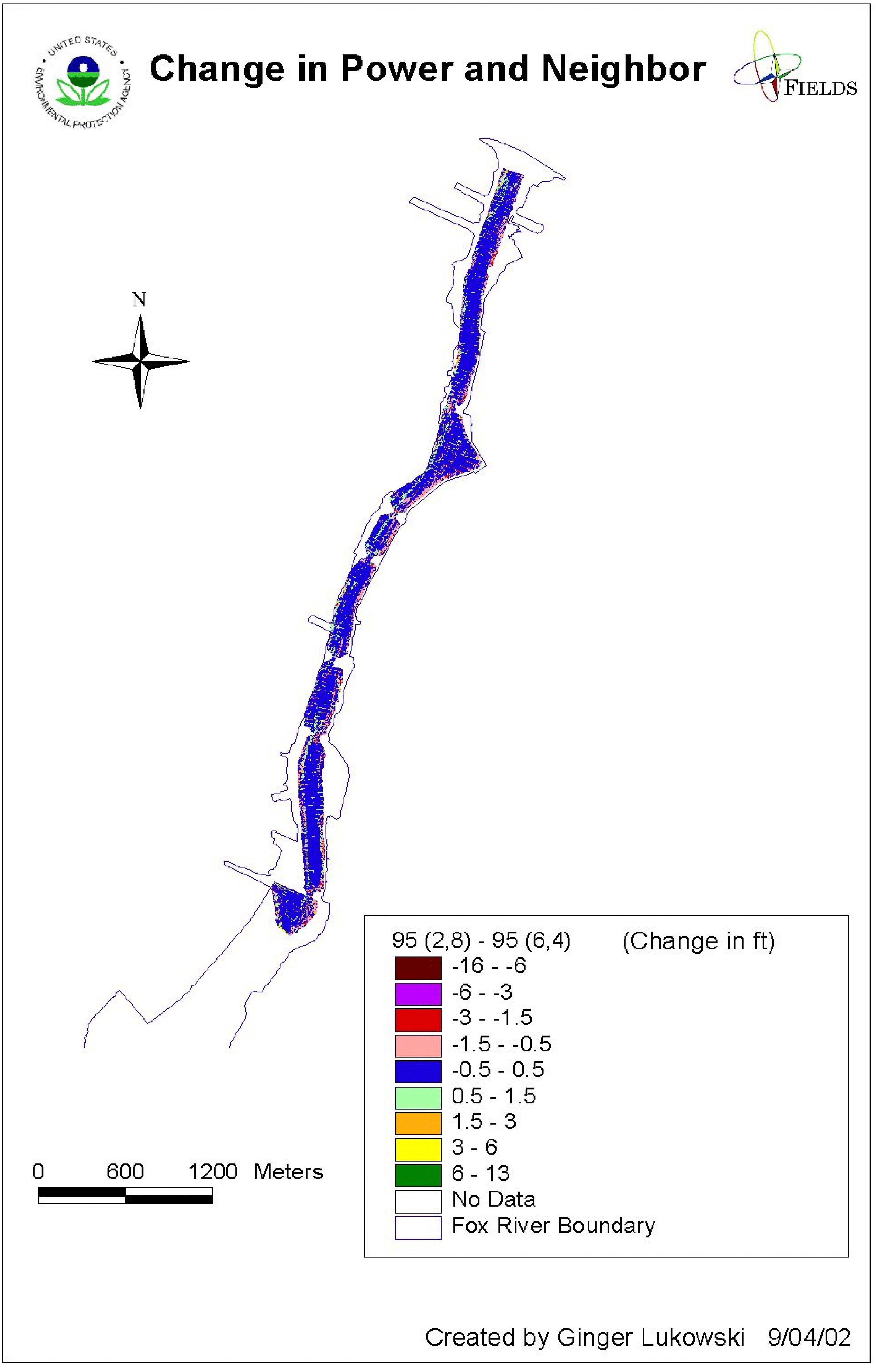

Change in Power and Neighbor
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
N
0
600
1200
Meters
95 (2,8) - 95 (6,4)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 9b**

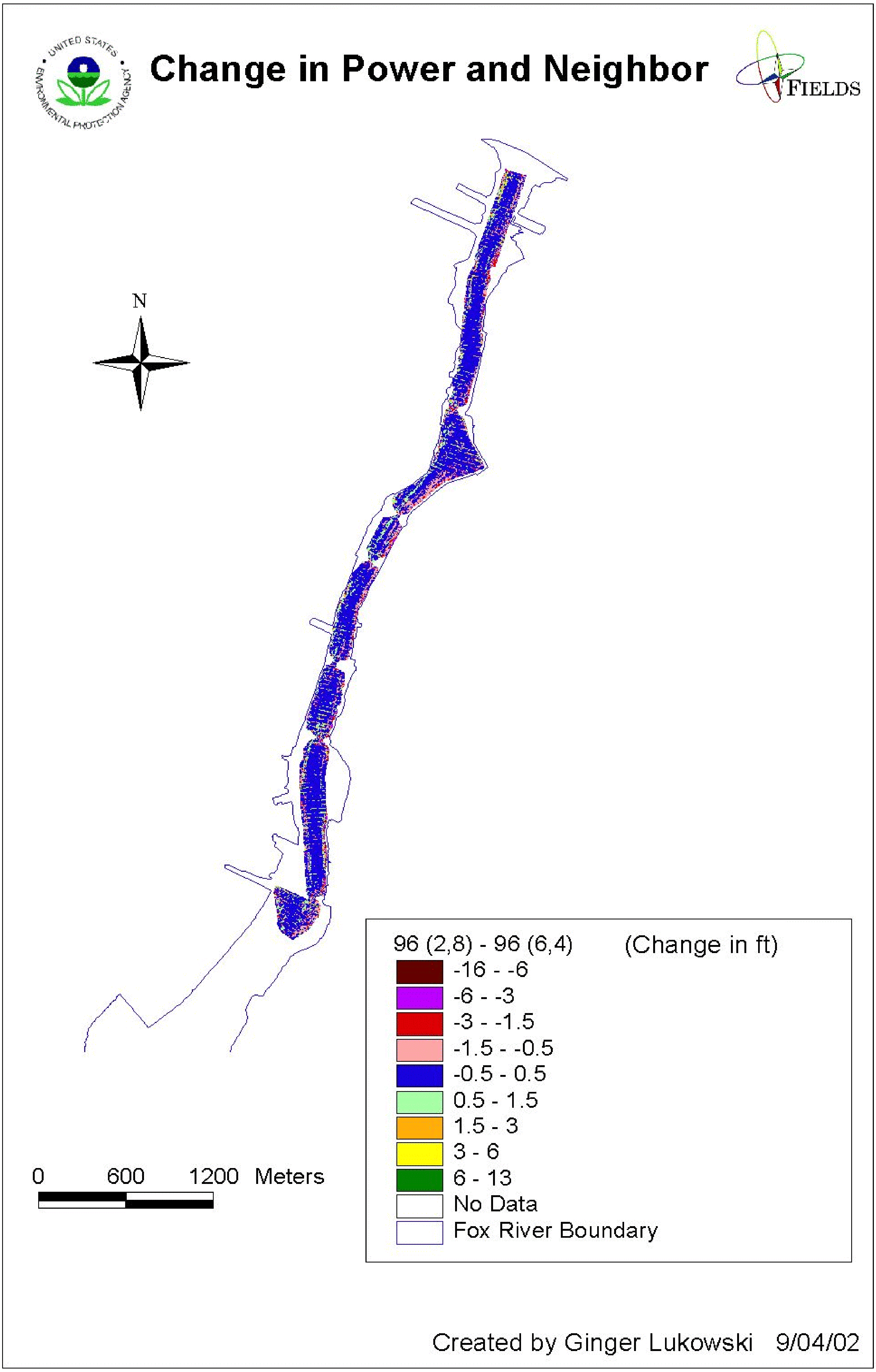
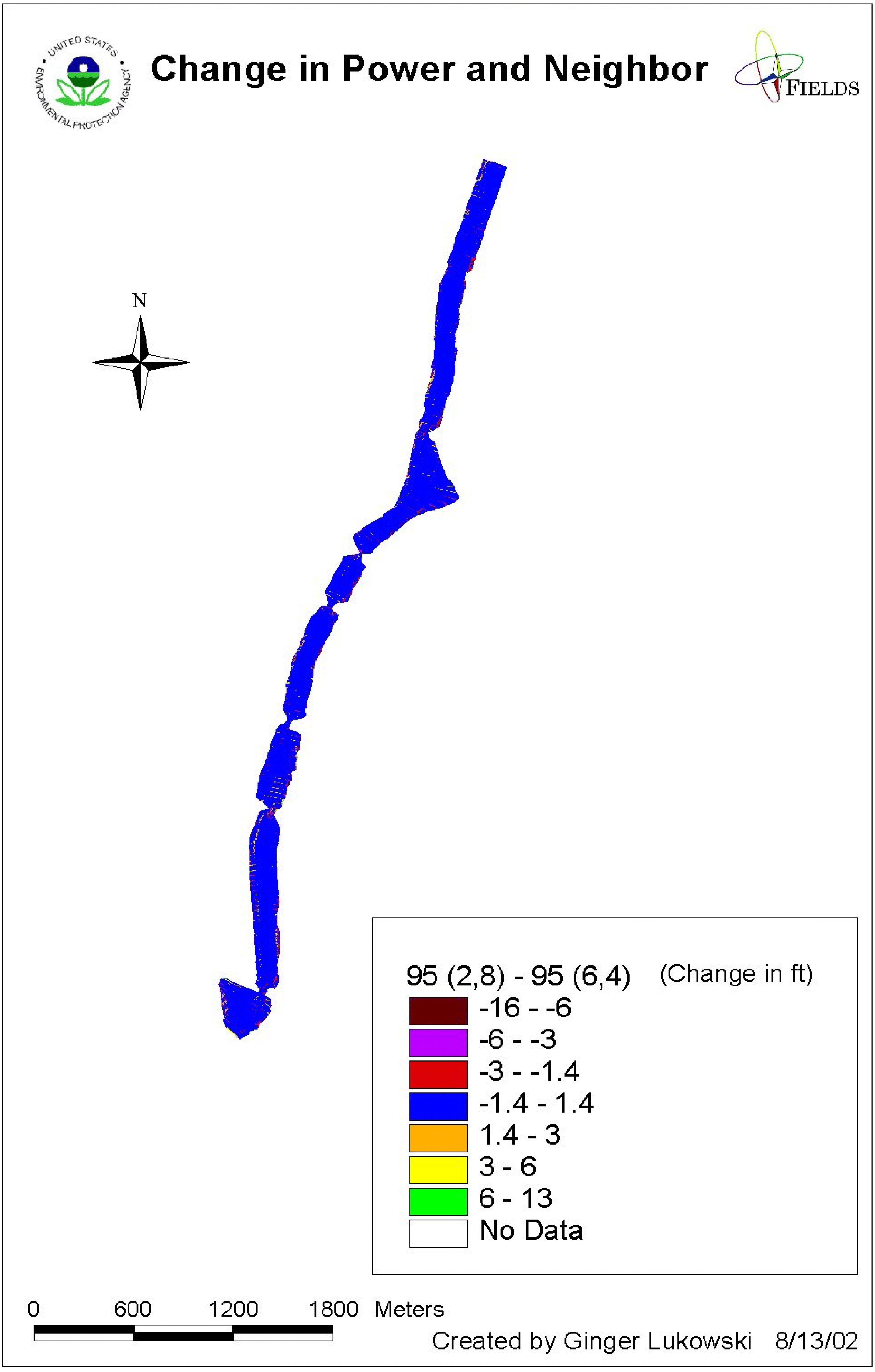
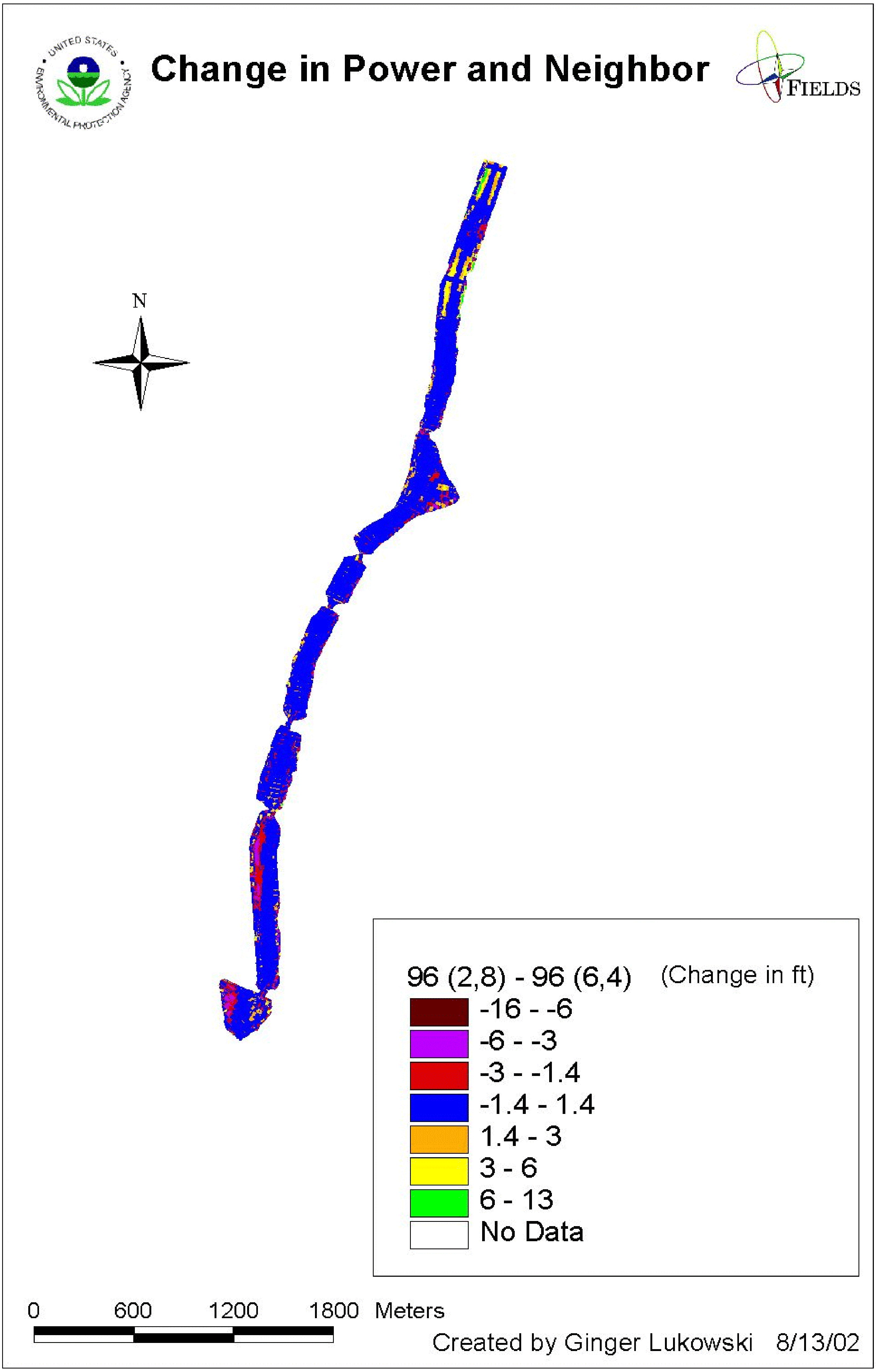

Change in Power and Neighbor
FIELDS
N
0 600 1200 Meters
96 (2,8) - 96 (6,4) (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 9c**



Change in Power and Neighbor
FIELDS
N
95 (2,8) - 95 (6,4)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
0
600
1200
1800
Meters
Created by Ginger Lukowski
8/13/02

**Figure 9d**



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Change in Power and Neighbor
FIELDS
N
96 (2,8) - 96 (6,4)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
0
600
1200
1800
Meters
Created by Ginger Lukowski 8/13/02

**Figure 10a**

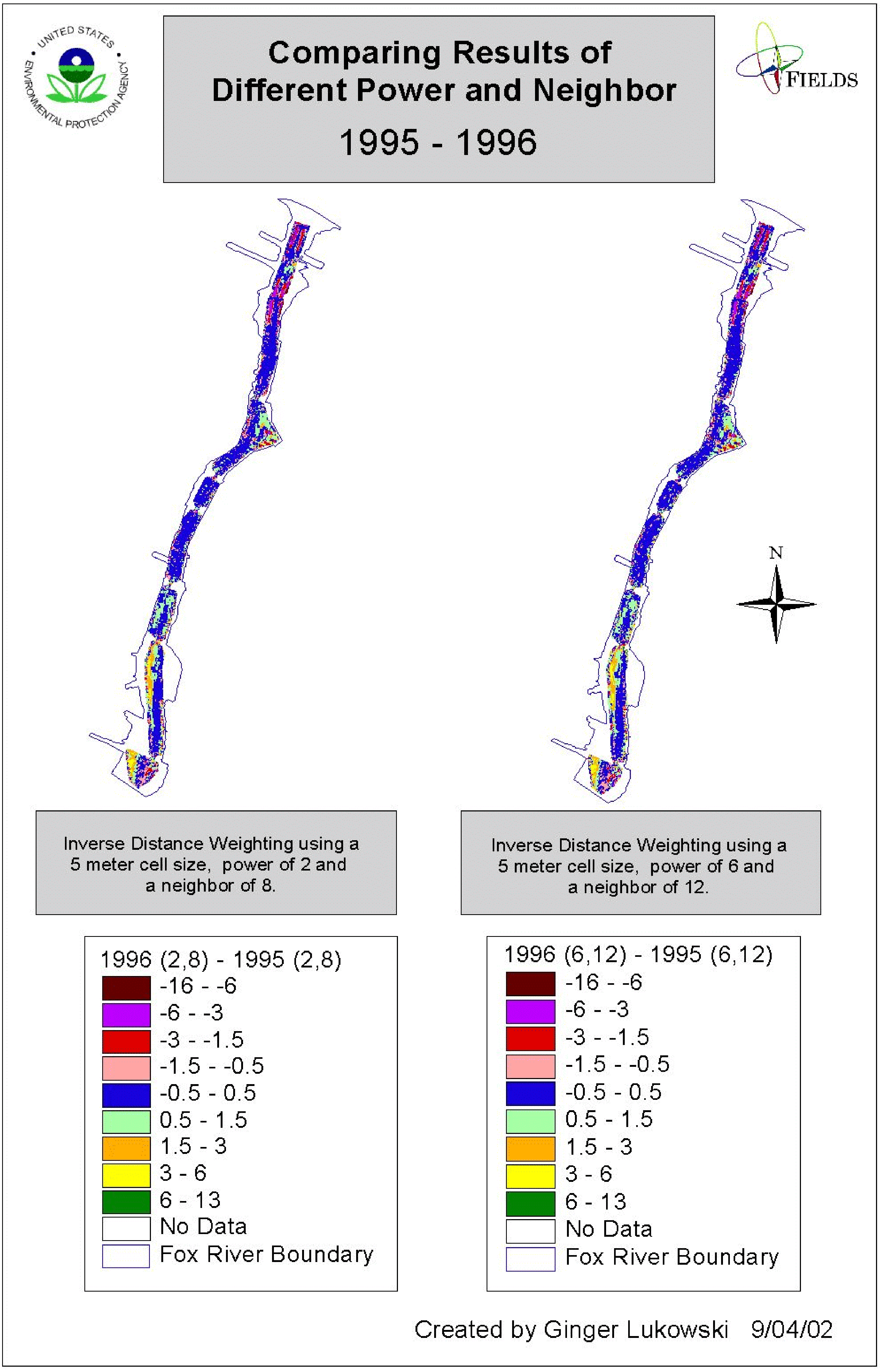

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Comparing Results of
Different Power and Neighbor
1995 - 1996
FIELDS
N
Inverse Distance Weighting using a
5 meter cell size, power of 2 and
a neighbor of 8.
Inverse Distance Weighting using a
5 meter cell size, power of 6 and
a neighbor of 12.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (6,12) - 1995 (6,12)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 10b**

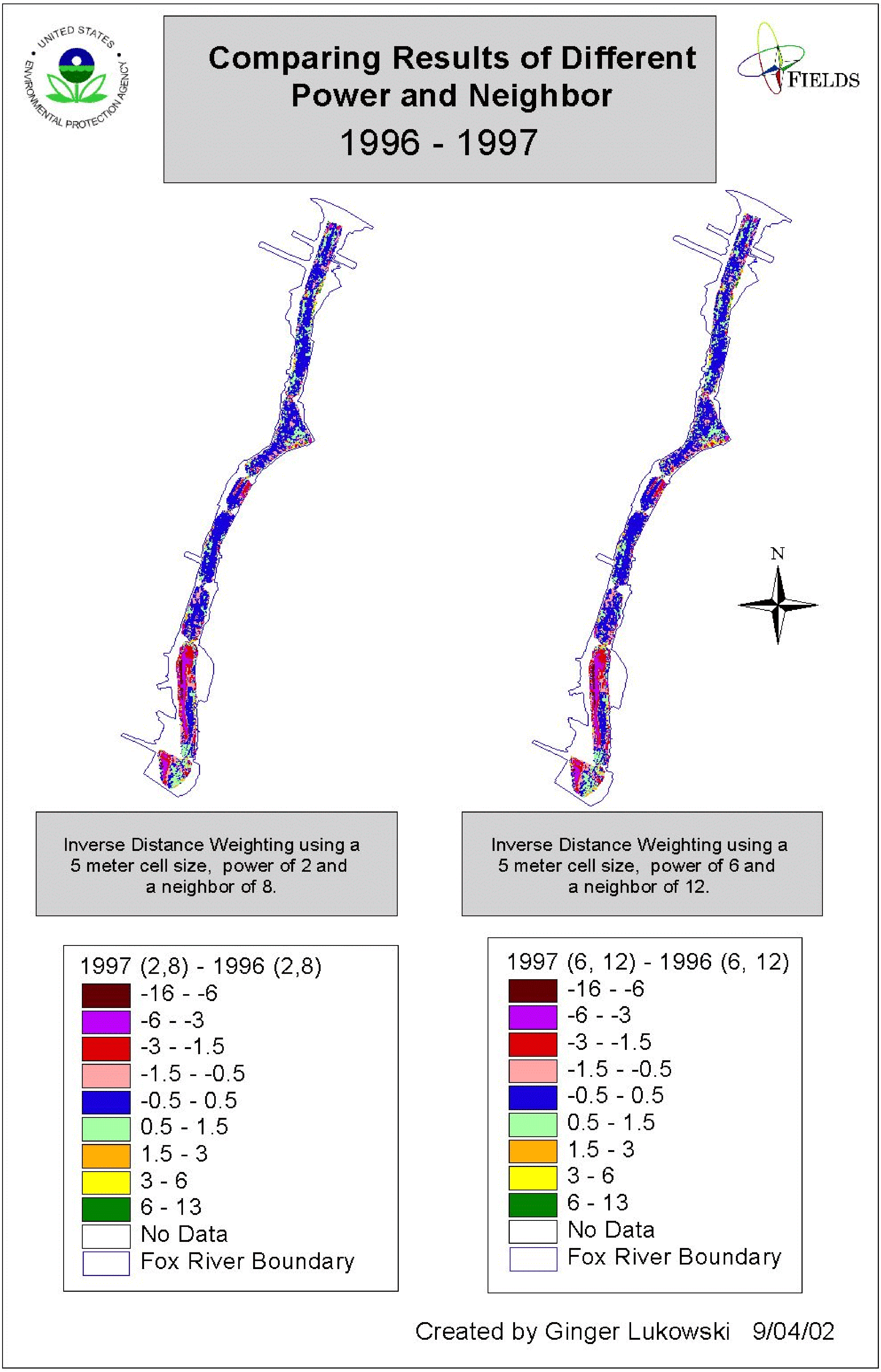

Comparing Results of Different Power and Neighbor
1996 - 1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 12.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (6, 12) - 1996 (6, 12)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 10c**

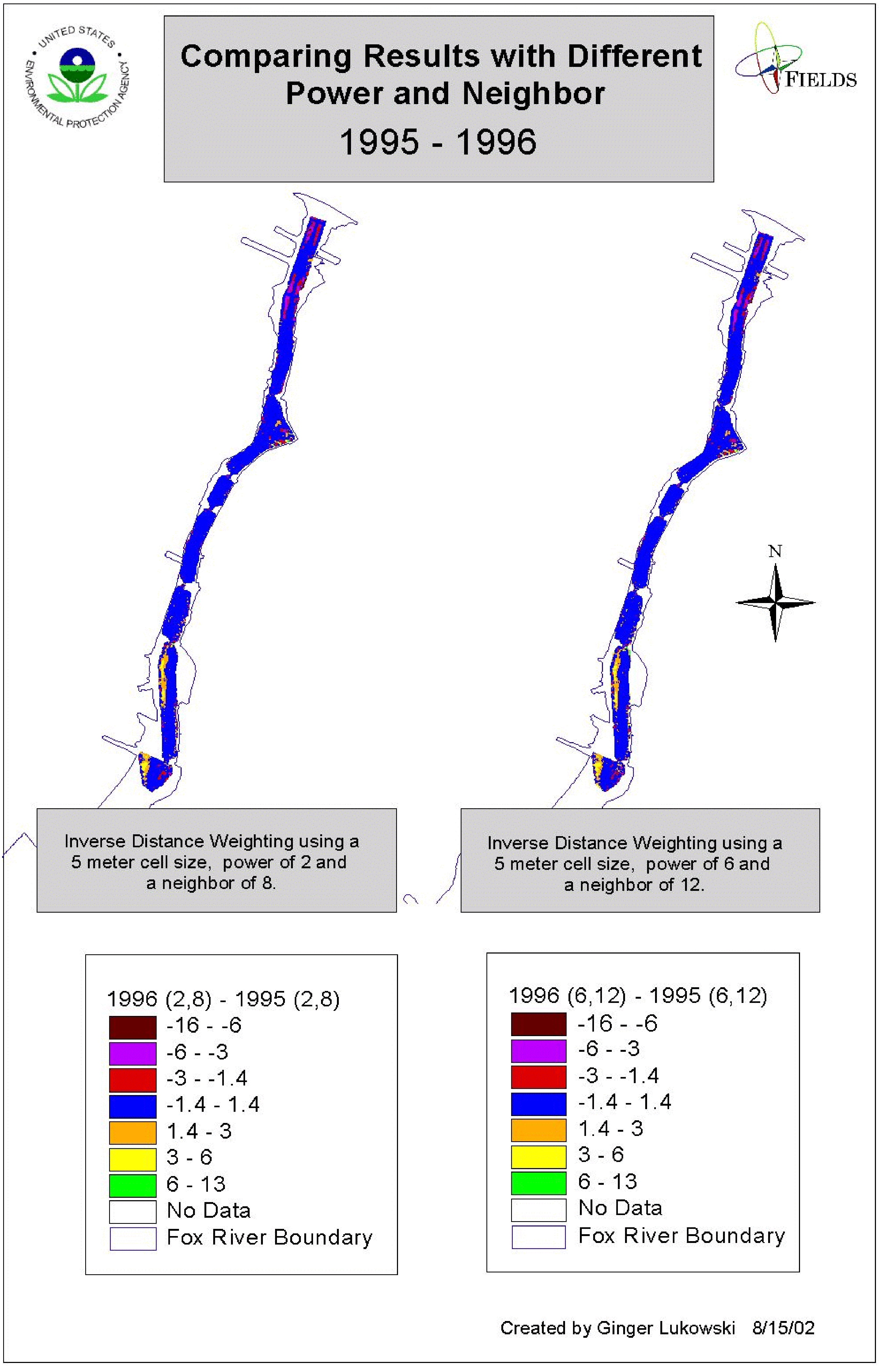

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Comparing Results with Different Power and Neighbor
1995 - 1996
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 12.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (6,12) - 1995 (6,12)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 8/15/02

**Figure 10d**

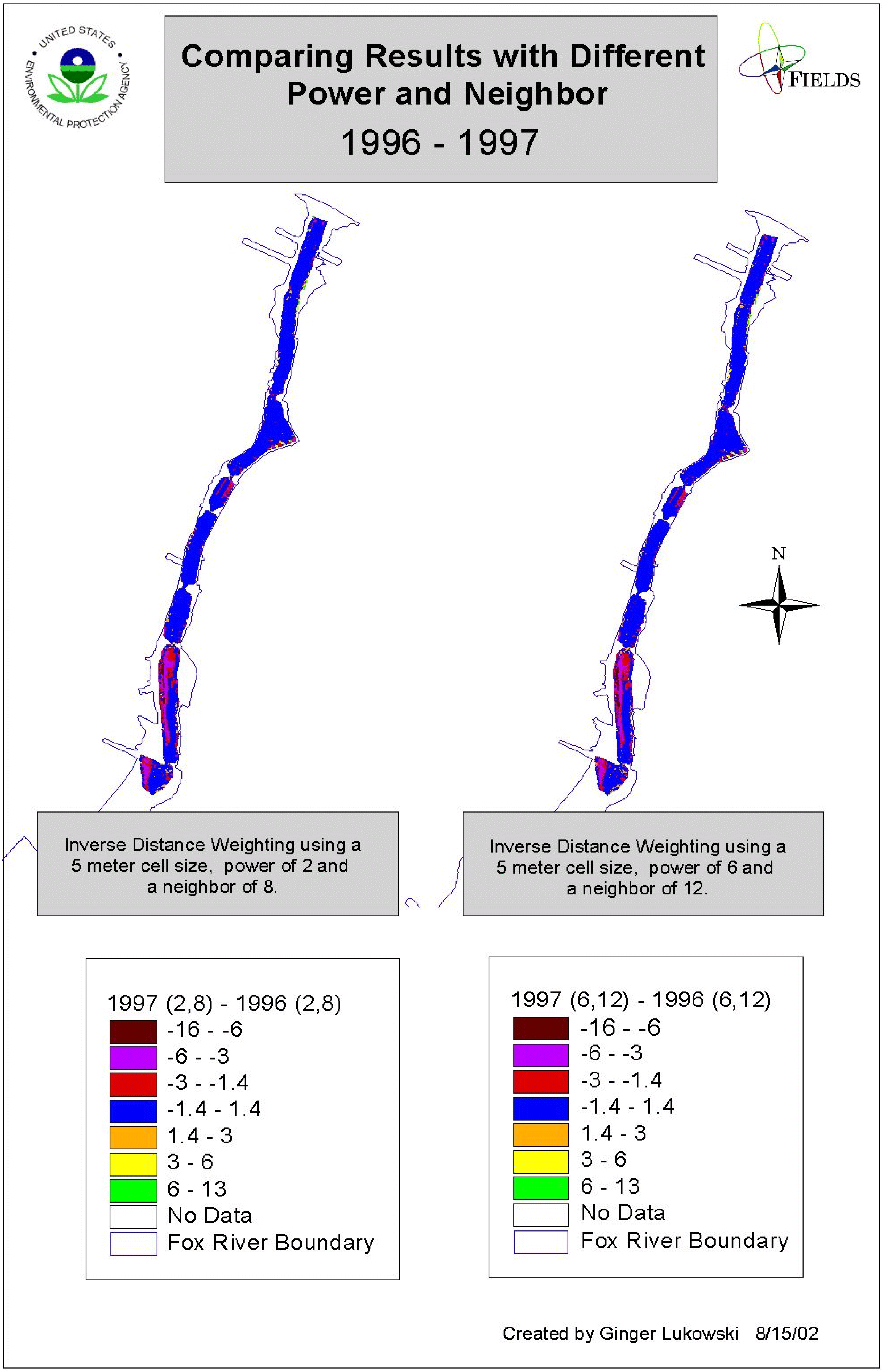
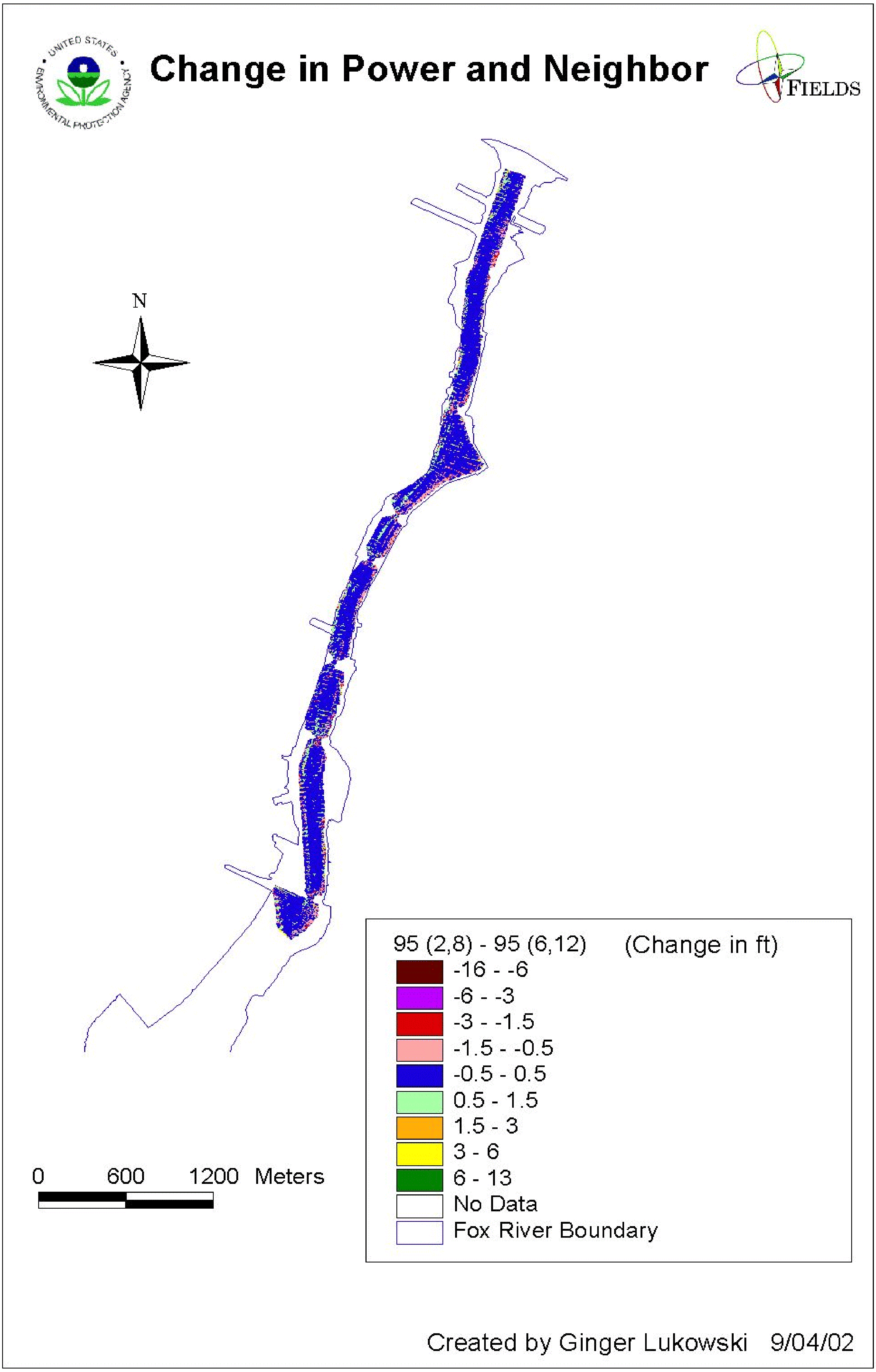

Comparing Results with Different Power and Neighbor
1996 - 1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Inverse Distance Weighting using a 5 meter cell size, power of 6 and a neighbor of 12.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (6,12) - 1996 (6,12)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 8/15/02

**Figure 11a**



Change in Power and Neighbor
FIELDS
N
95 (2,8) - 95 (6,12)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
600
1200
Meters
Created by Ginger Lukowski 9/04/02

**Figure 11b**

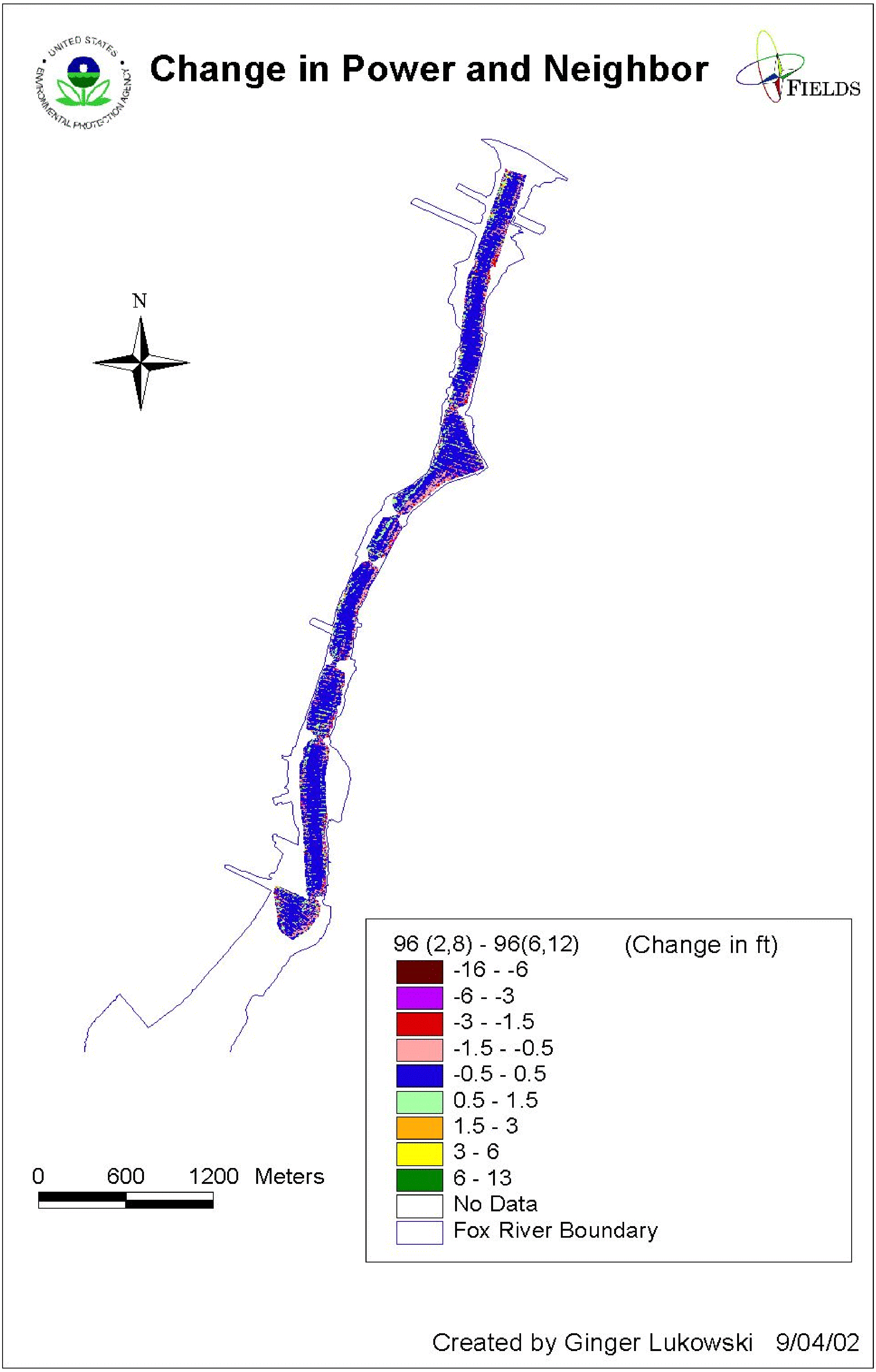

Change in Power and Neighbor
FIELDS
N
0 600 1200 Meters
96 (2,8) - 96(6,12) (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 11c**

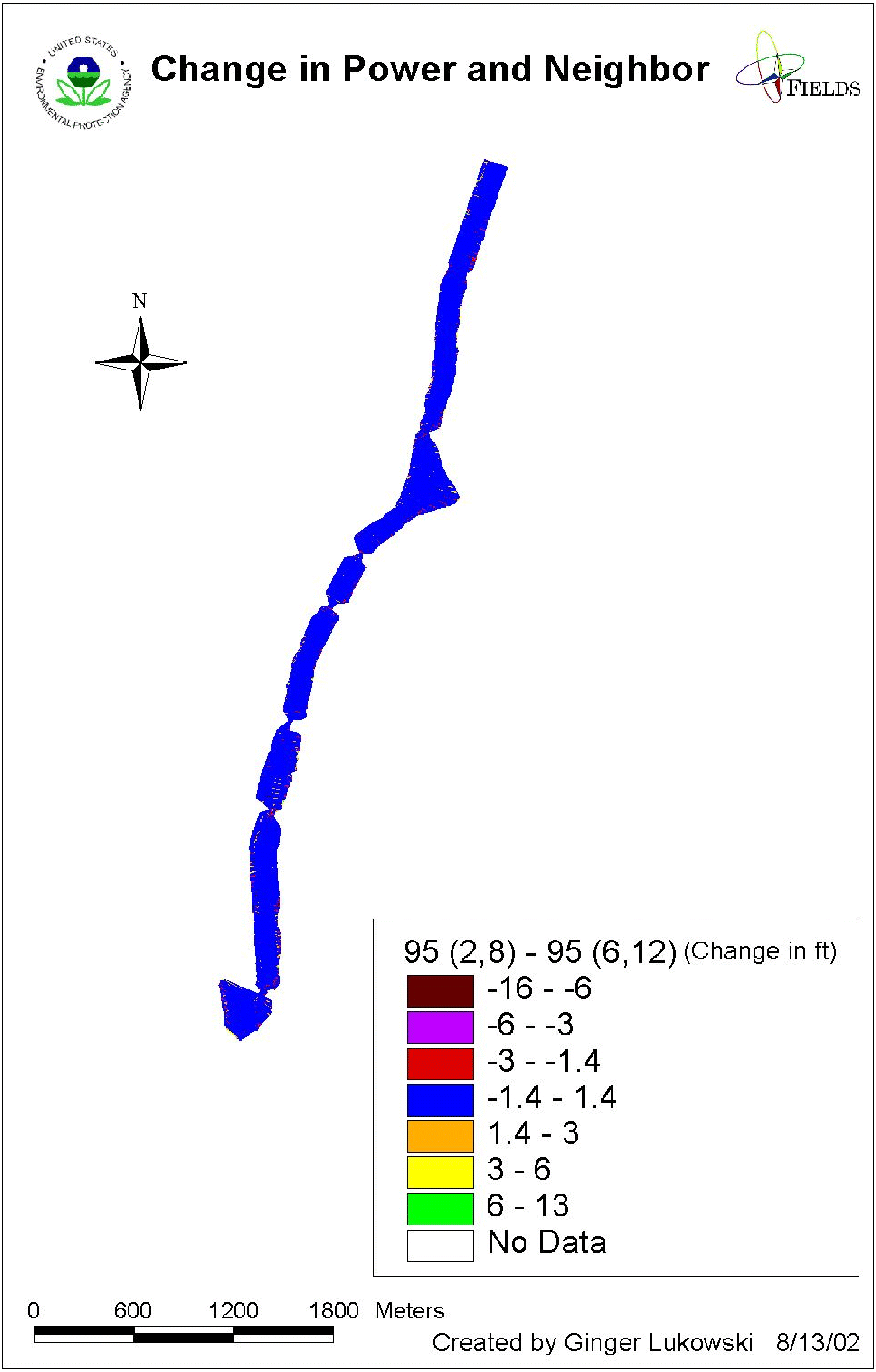

Change in Power and Neighbor
FIELDS
N
95 (2,8) - 95 (6,12) (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
0 600 1200 1800 Meters
Created by Ginger Lukowski 8/13/02

**Figure 11d**

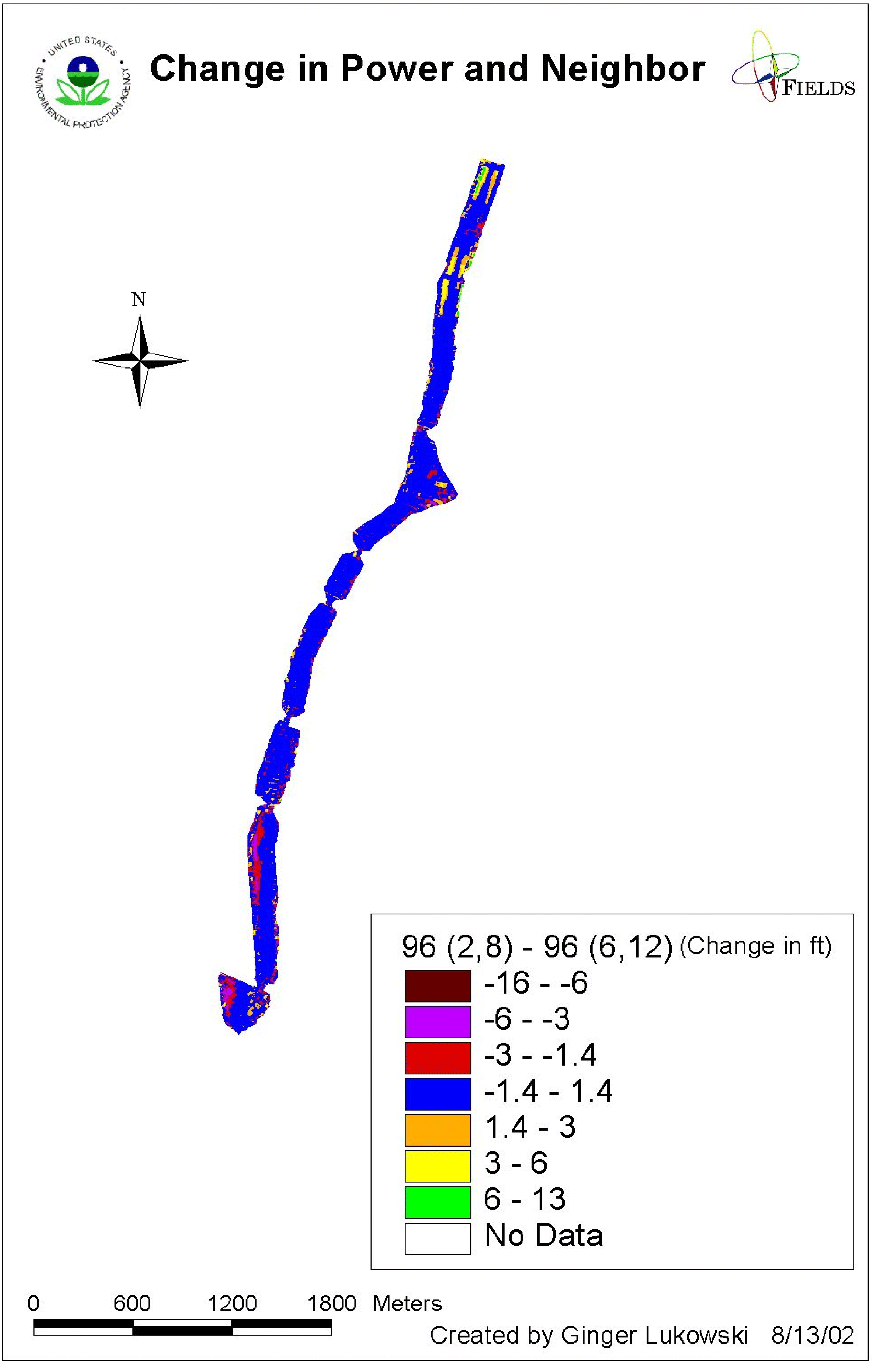

Change in Power and Neighbor
FIELDS
N
96 (2,8) - 96 (6,12) (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
0 600 1200 1800 Meters
Created by Ginger Lukowski 8/13/02

**Figure 12a**

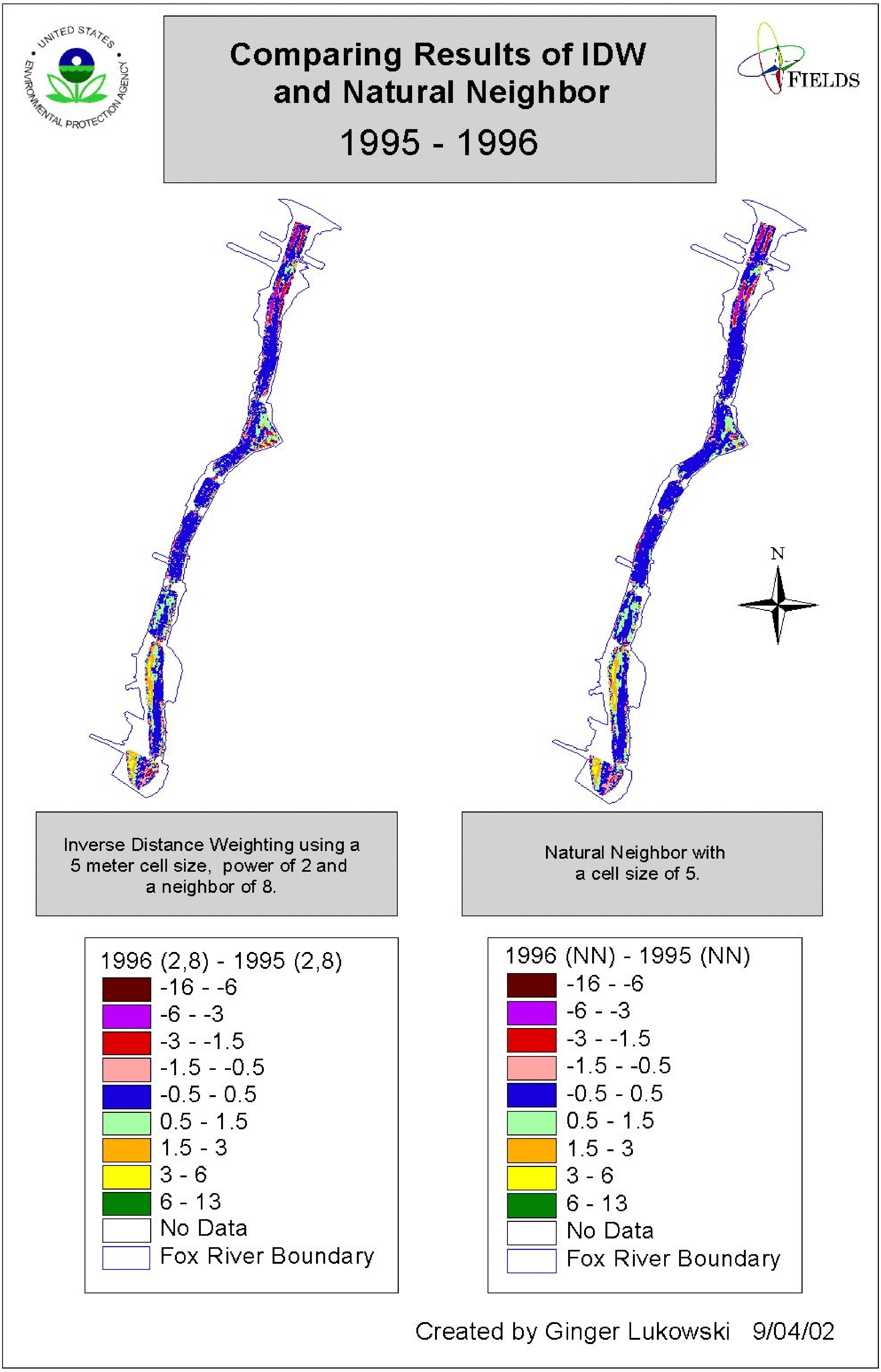

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
Comparing Results of IDW and Natural Neighbor
1995 - 1996
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Natural Neighbor with a cell size of 5.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (NN) - 1995 (NN)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 12b**

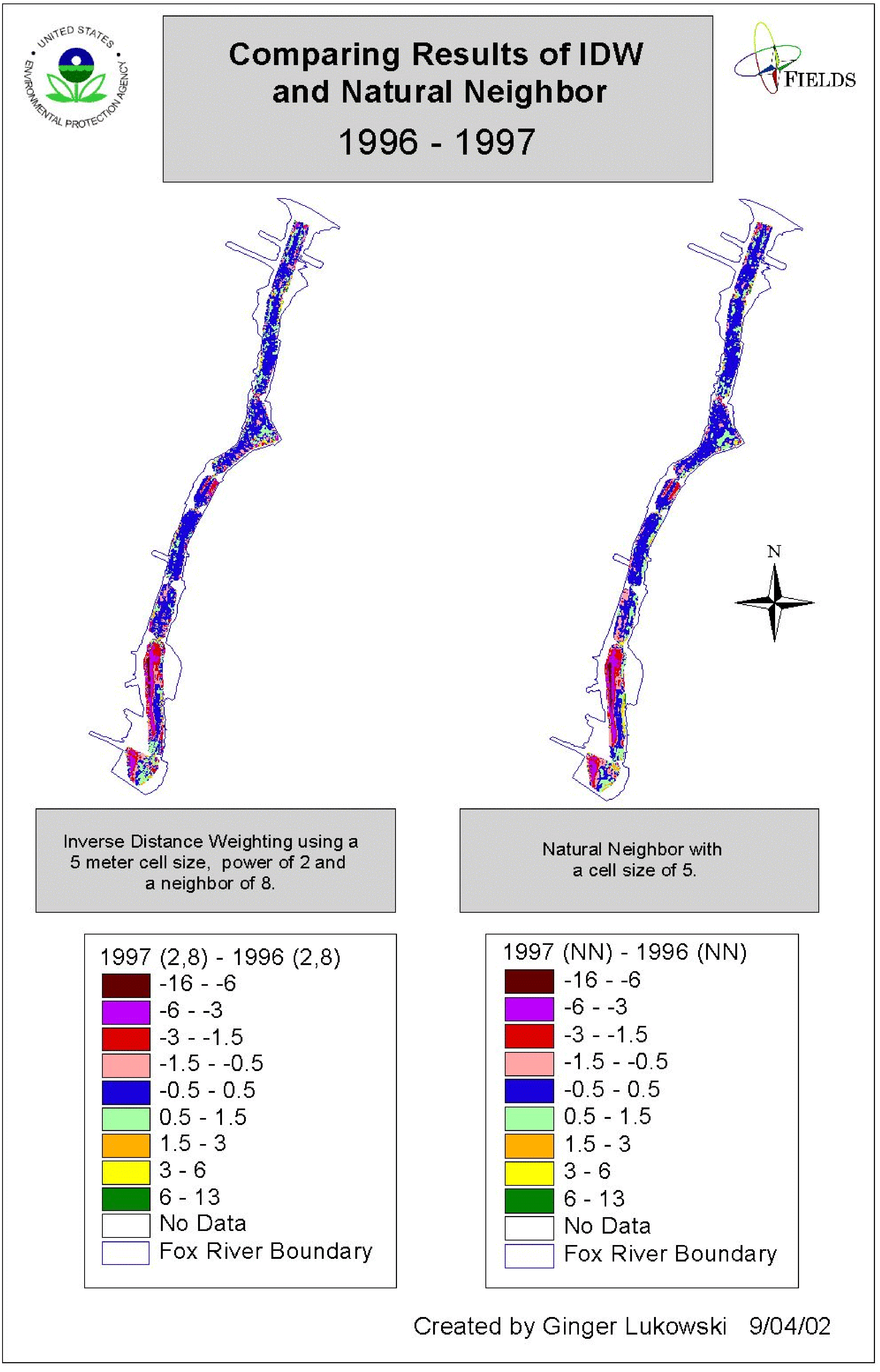
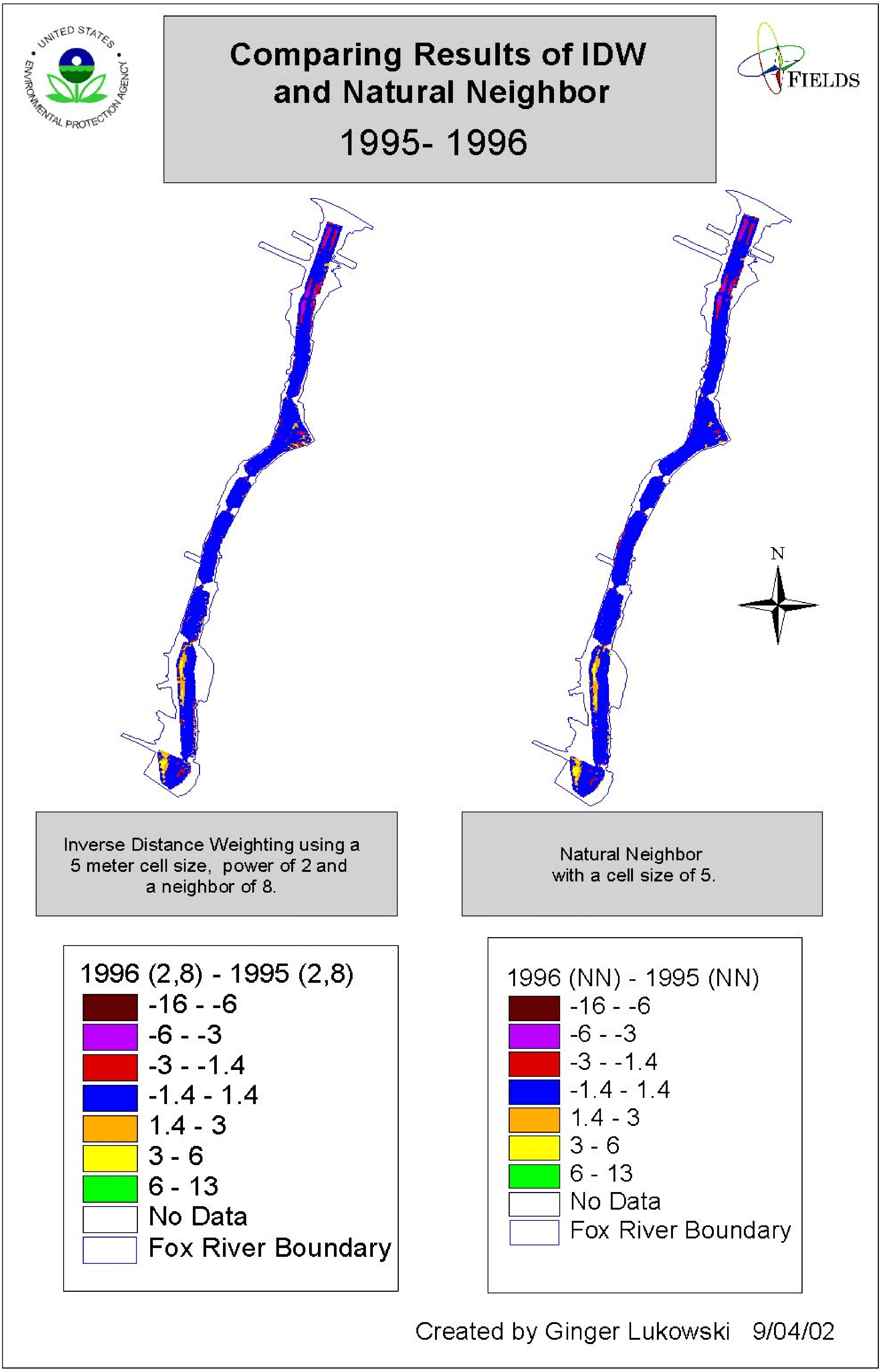

Comparing Results of IDW
and Natural Neighbor
1996 - 1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Natural Neighbor with a cell size of 5.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (NN) - 1996 (NN)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 12c**



Comparing Results of IDW and Natural Neighbor
1995- 1996
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Natural Neighbor with a cell size of 5.
1996 (2,8) - 1995 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 (NN) - 1995 (NN)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 12d**

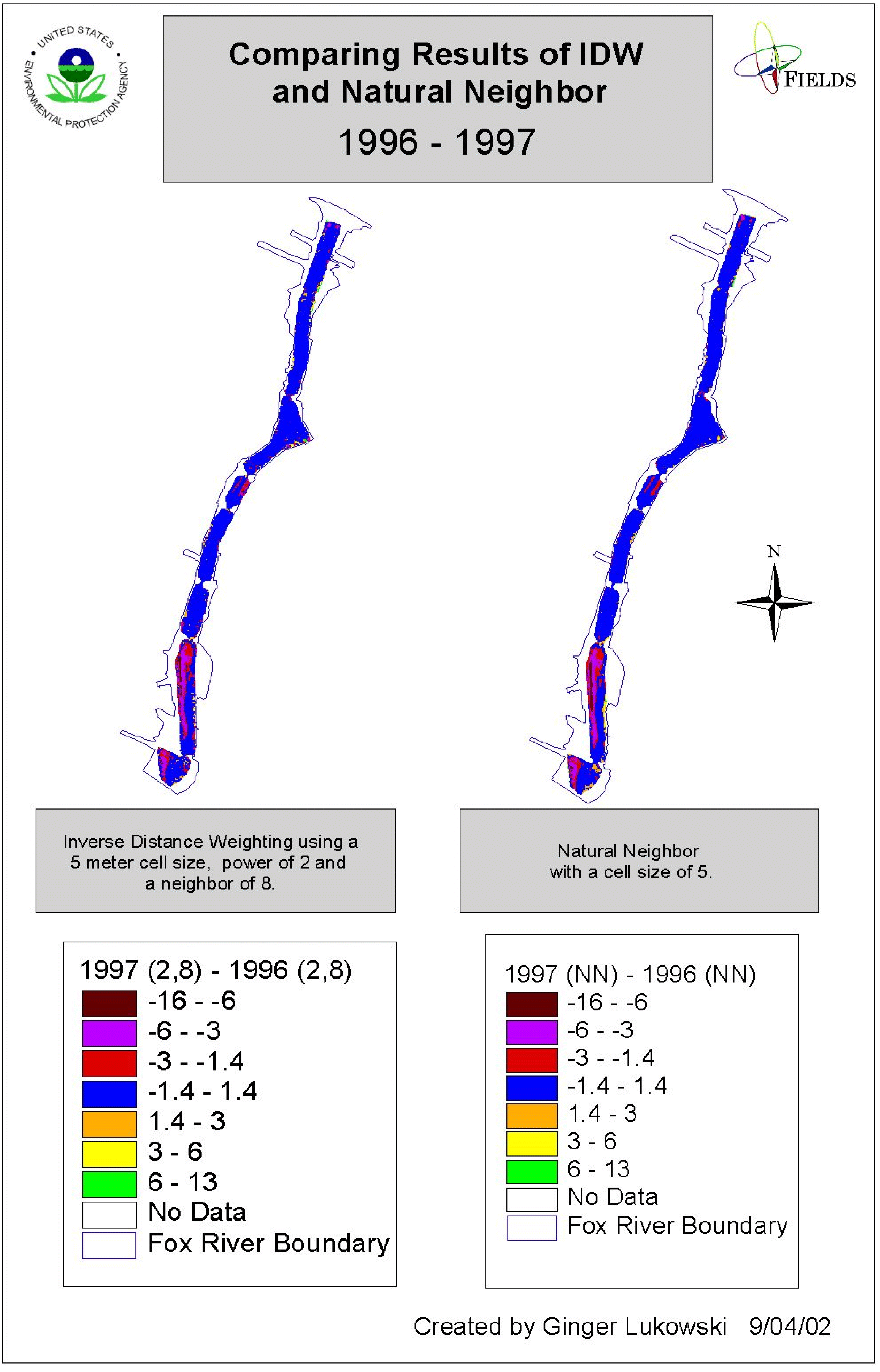
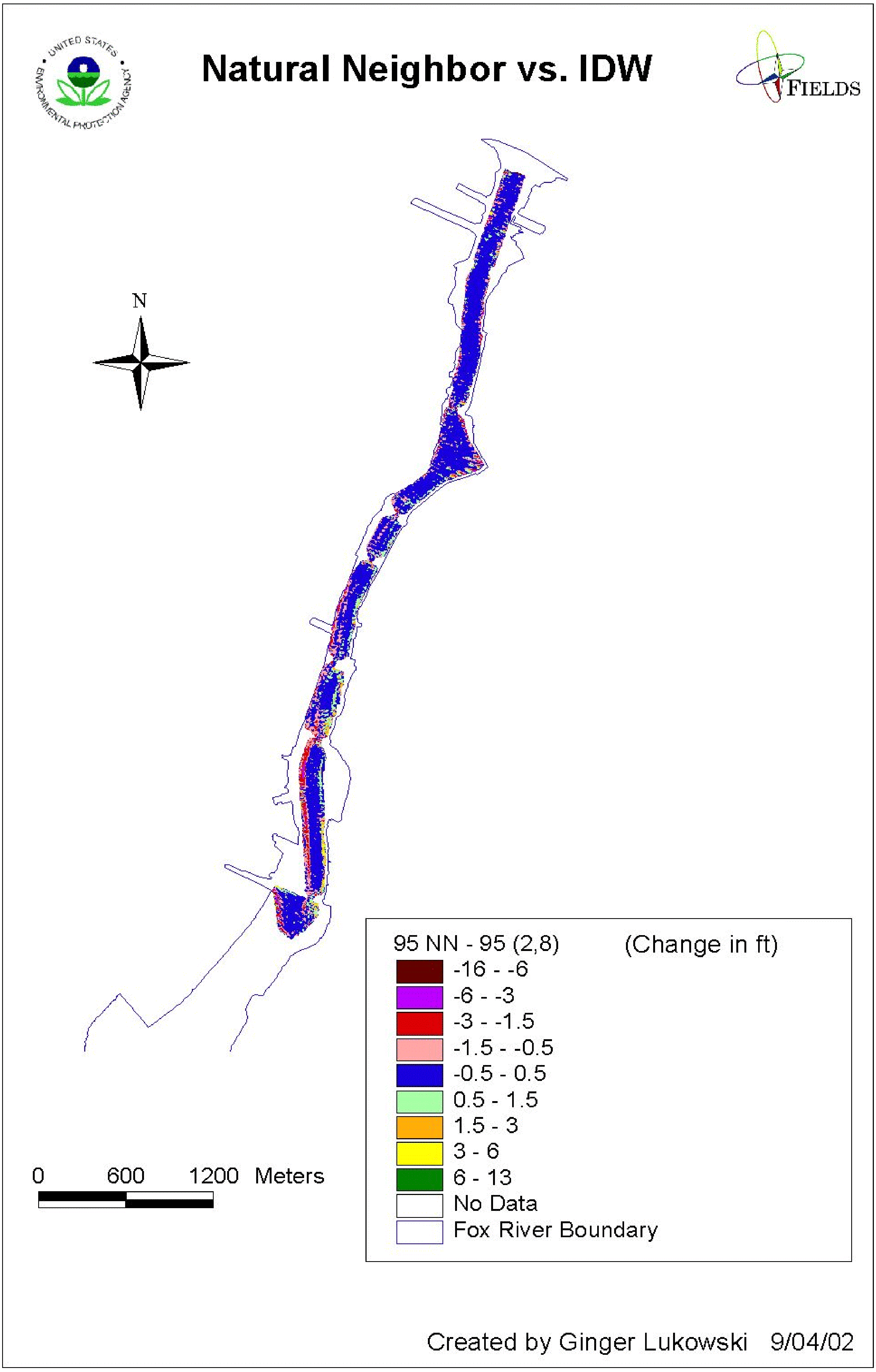
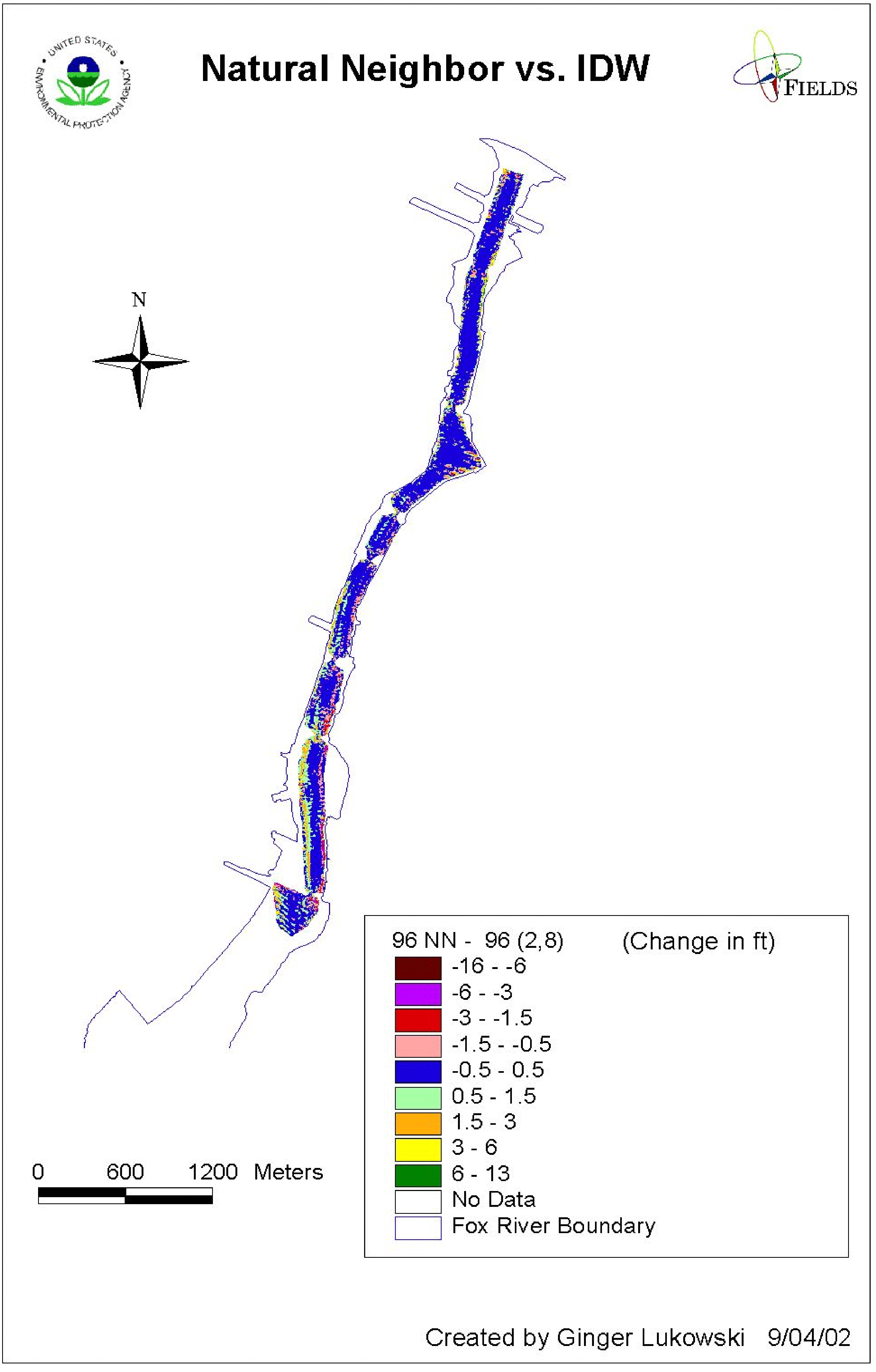

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Comparing Results of IDW and Natural Neighbor
1996 - 1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2 and a neighbor of 8.
Natural Neighbor with a cell size of 5.
1997 (2,8) - 1996 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 (NN) - 1996 (NN)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 13a**



Natural Neighbor vs. IDW
FIELDS
N
0
600
1200 Meters
95 NN - 95 (2,8)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 13b**



Natural Neighbor vs. IDW
FIELDS
N
0
600
1200
Meters
96 NN - 96 (2,8)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 13c**

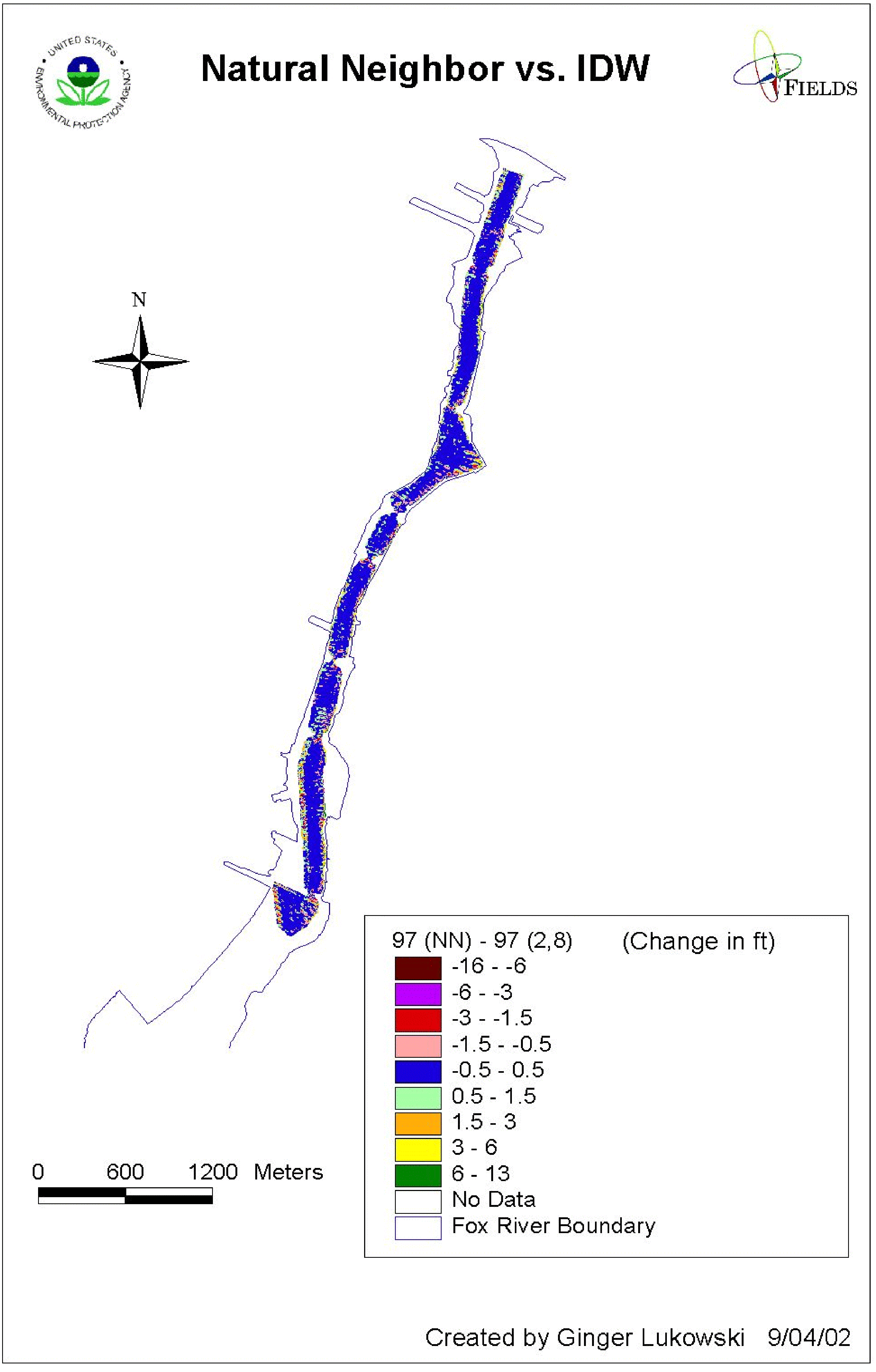
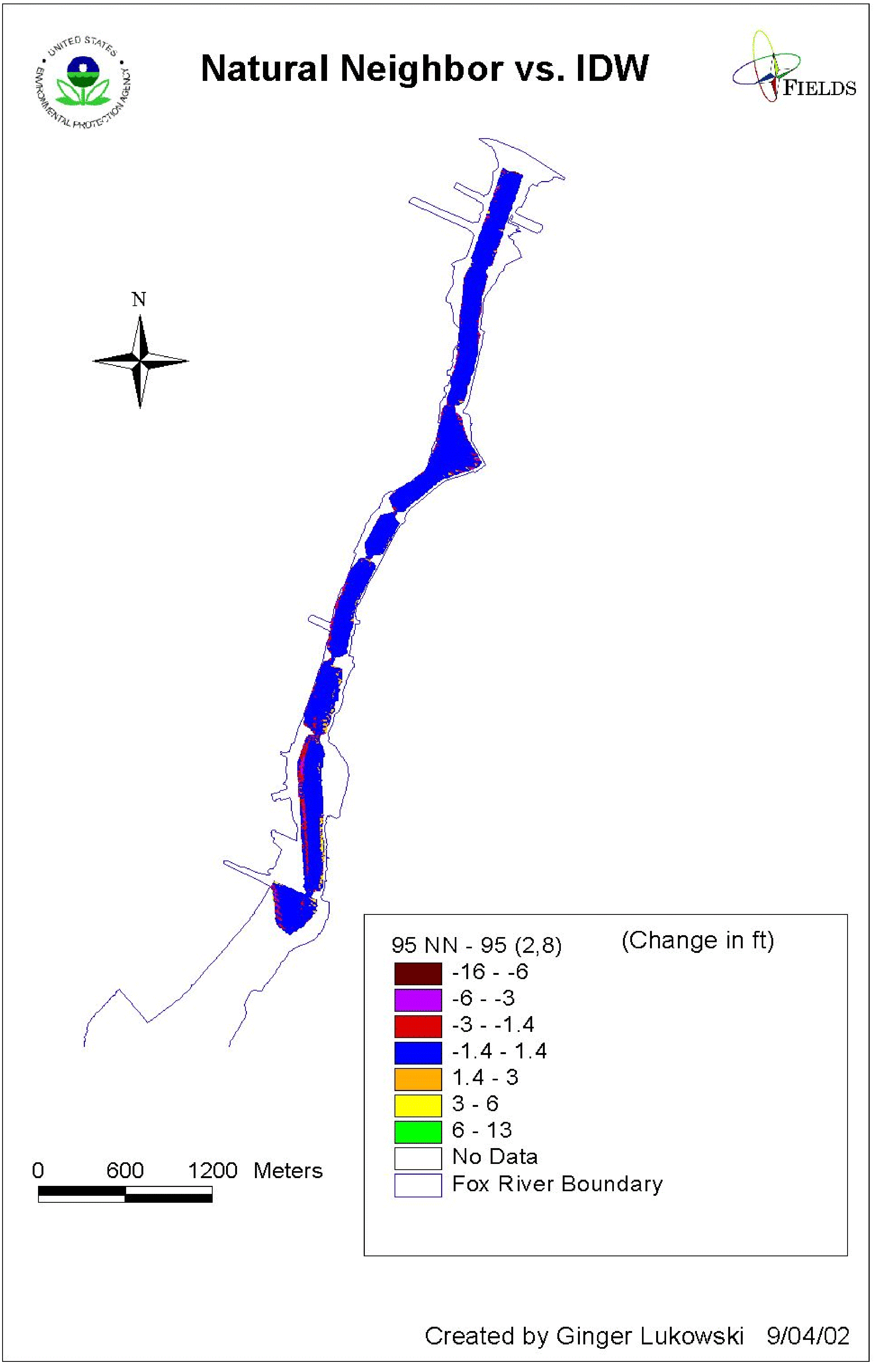

Natural Neighbor vs. IDW
FIELDS
N
0
600
1200
Meters
97 (NN) - 97 (2,8)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 13d**



Natural Neighbor vs. IDW
FIELDS
N
95 NN - 95 (2,8)
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
600
1200
Meters
Created by Ginger Lukowski 9/04/02

**Figure 13e**

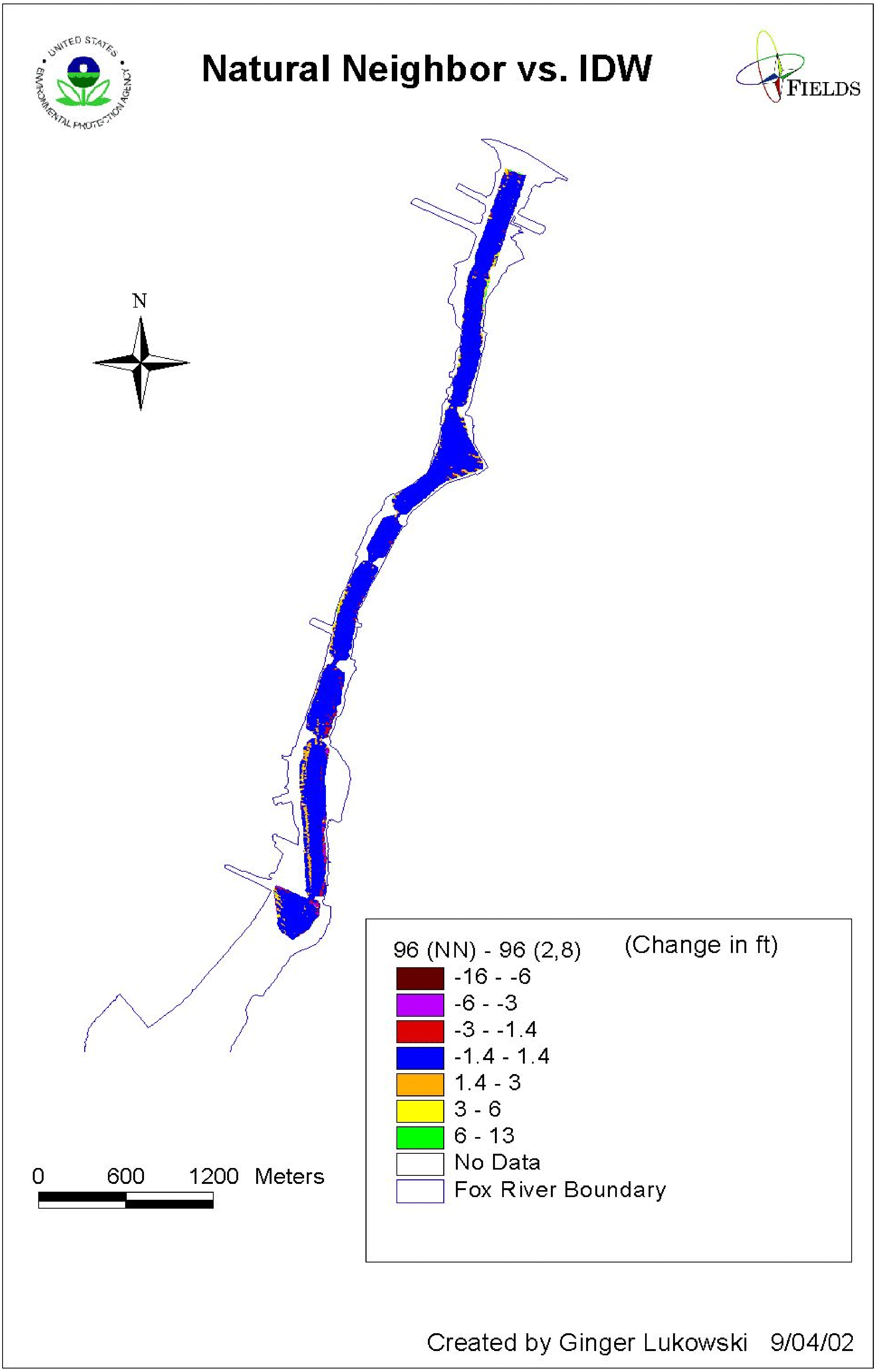
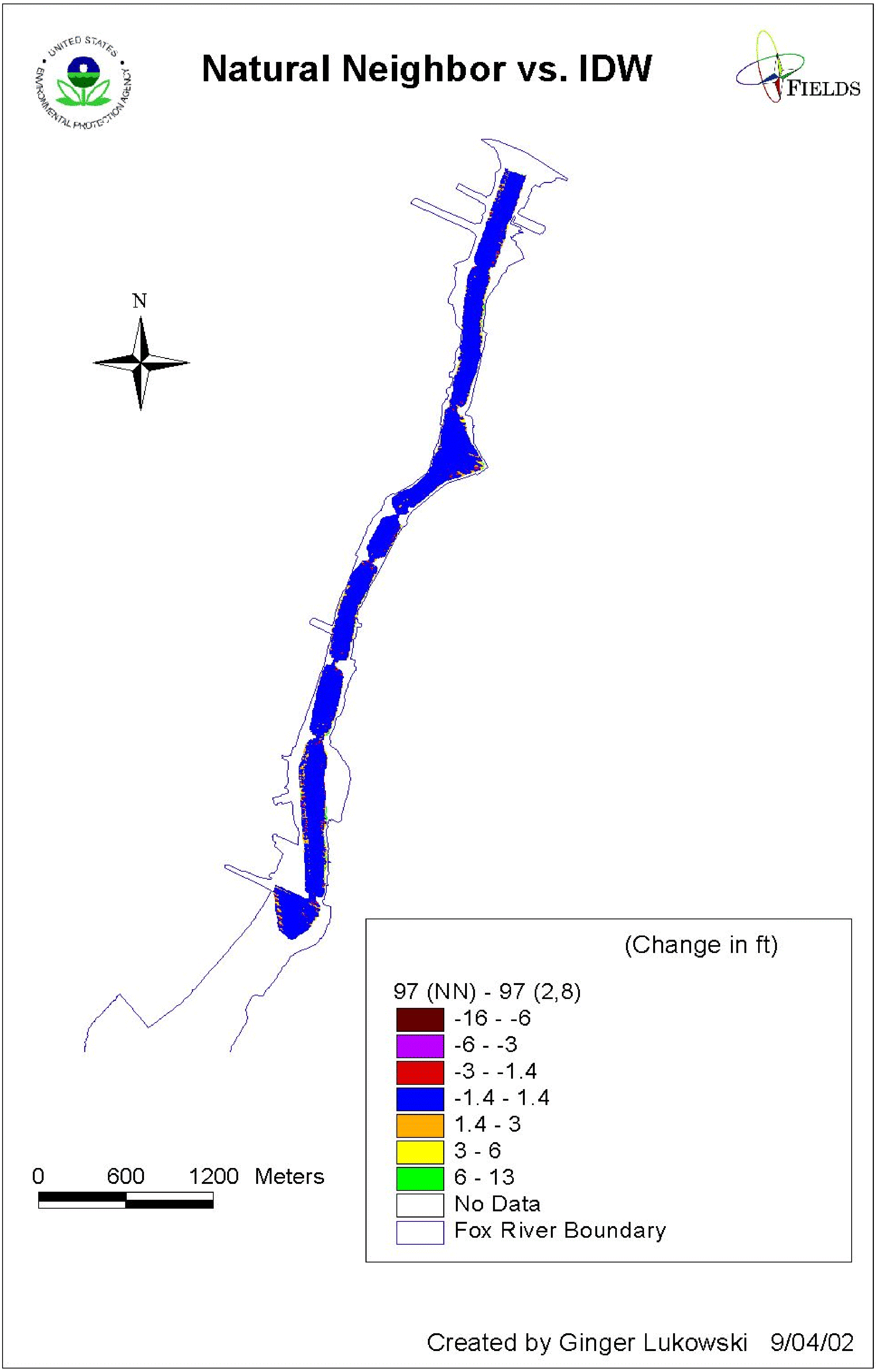

Natural Neighbor vs. IDW
FIELDS
N
0 600 1200 Meters
96 (NN) - 96 (2,8) (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 13f**



Natural Neighbor vs. IDW
FIELDS
N
0
600
1200
Meters
(Change in ft)
97 (NN) - 97 (2,8)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/04/02

**Figure 14a**

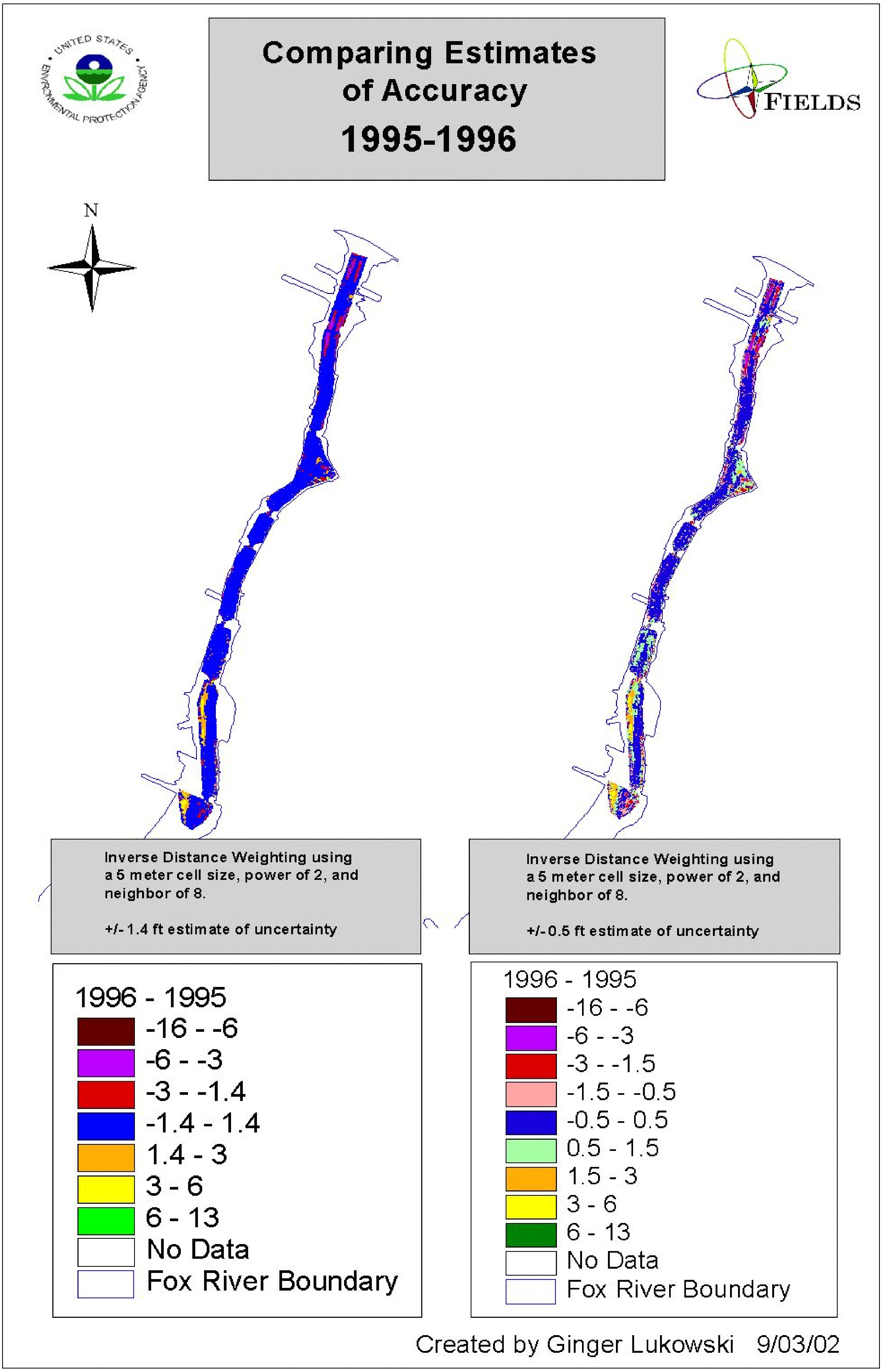
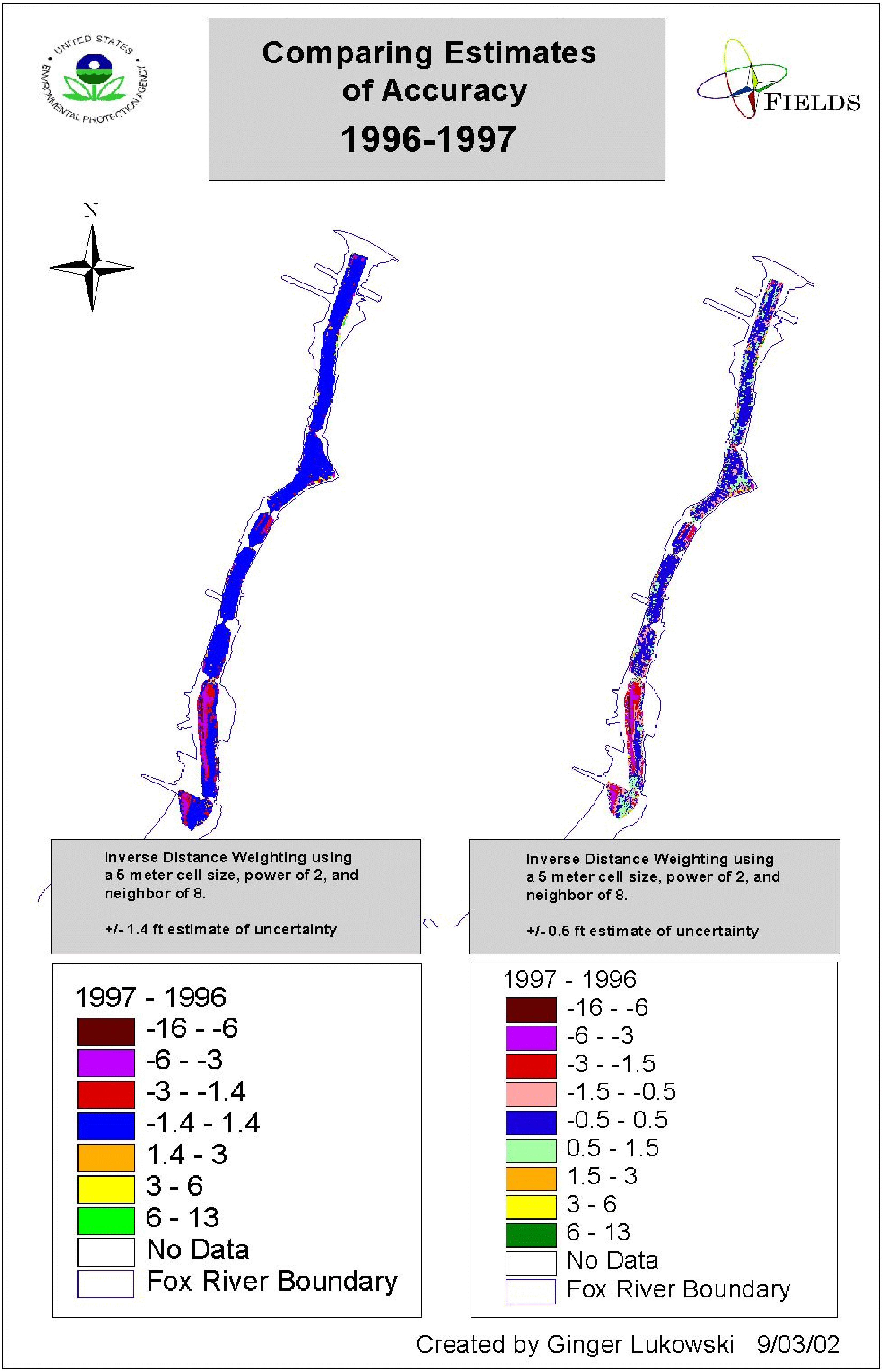

Comparing Estimates
of Accuracy
1995-1996
N
FIELDS
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 0.5 ft estimate of uncertainty
1996 - 1995
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 - 1995
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

**Figure 14b**



Comparing Estimates of Accuracy
1996-1997
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2, and neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using a 5 meter cell size, power of 2, and neighbor of 8.
+/- 0.5 ft estimate of uncertainty
1997 - 1996
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1997 - 1996
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

**Figure 14c**

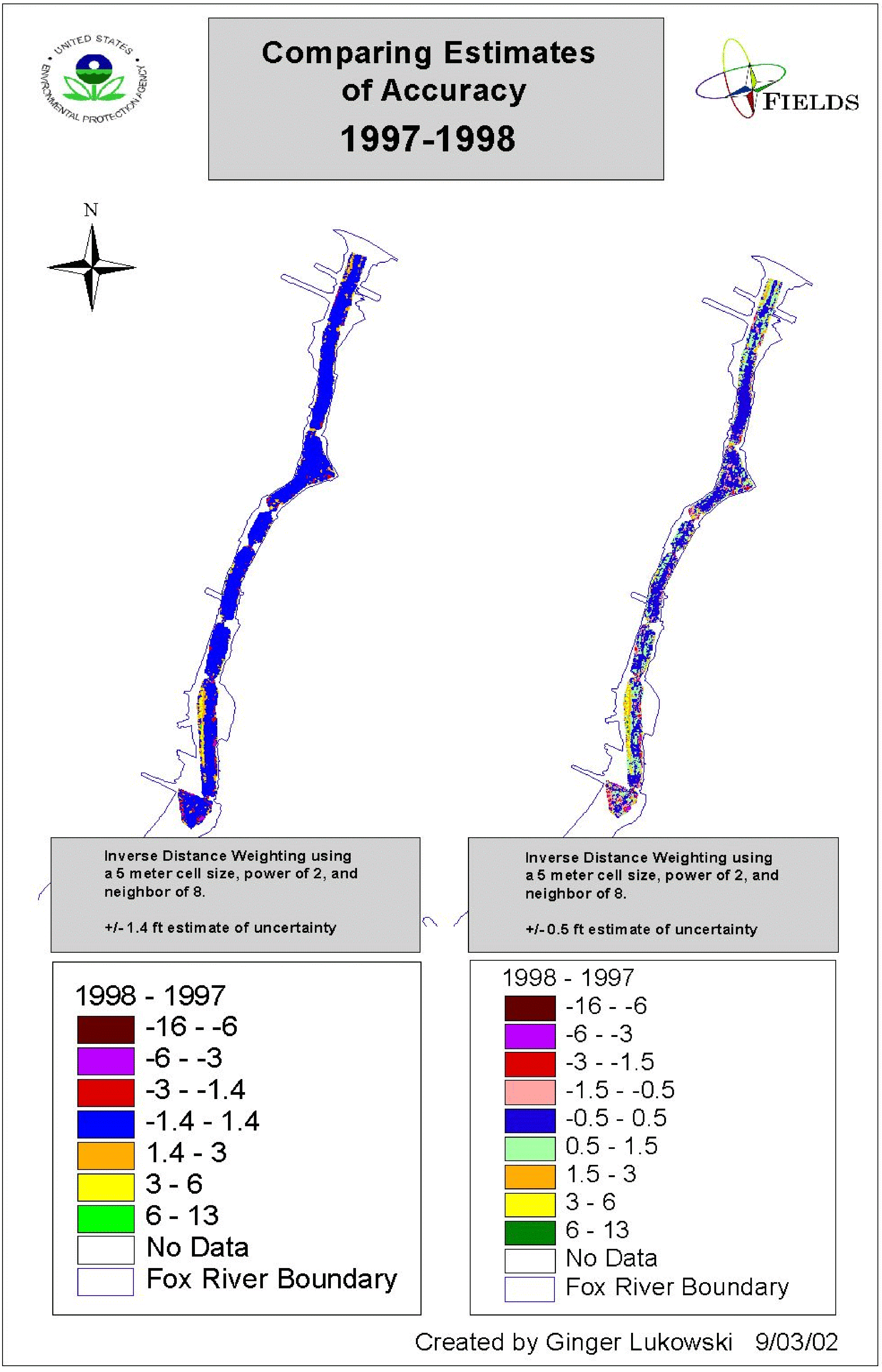
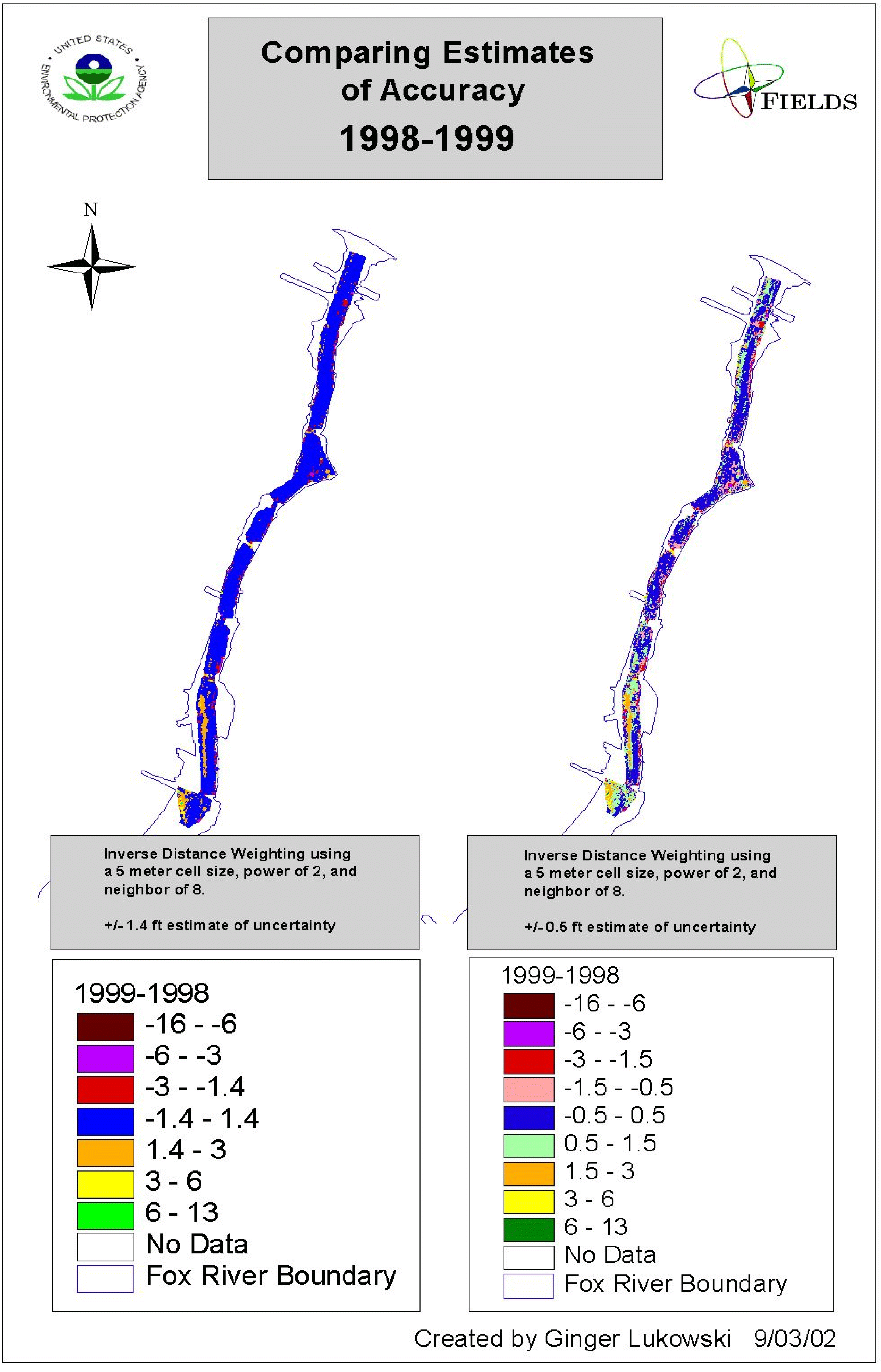

Comparing Estimates
of Accuracy
1997-1998
FIELDS
N
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 0.5 ft estimate of uncertainty
1998 - 1997
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1998 - 1997
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

**Figure 14d**



Comparing Estimates of Accuracy
1998-1999
FIELDS
N
Inverse Distance Weighting using a 5 meter cell size, power of 2, and neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using a 5 meter cell size, power of 2, and neighbor of 8.
+/- 0.5 ft estimate of uncertainty
1999-1998
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1999-1998
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

**Figure 14e**

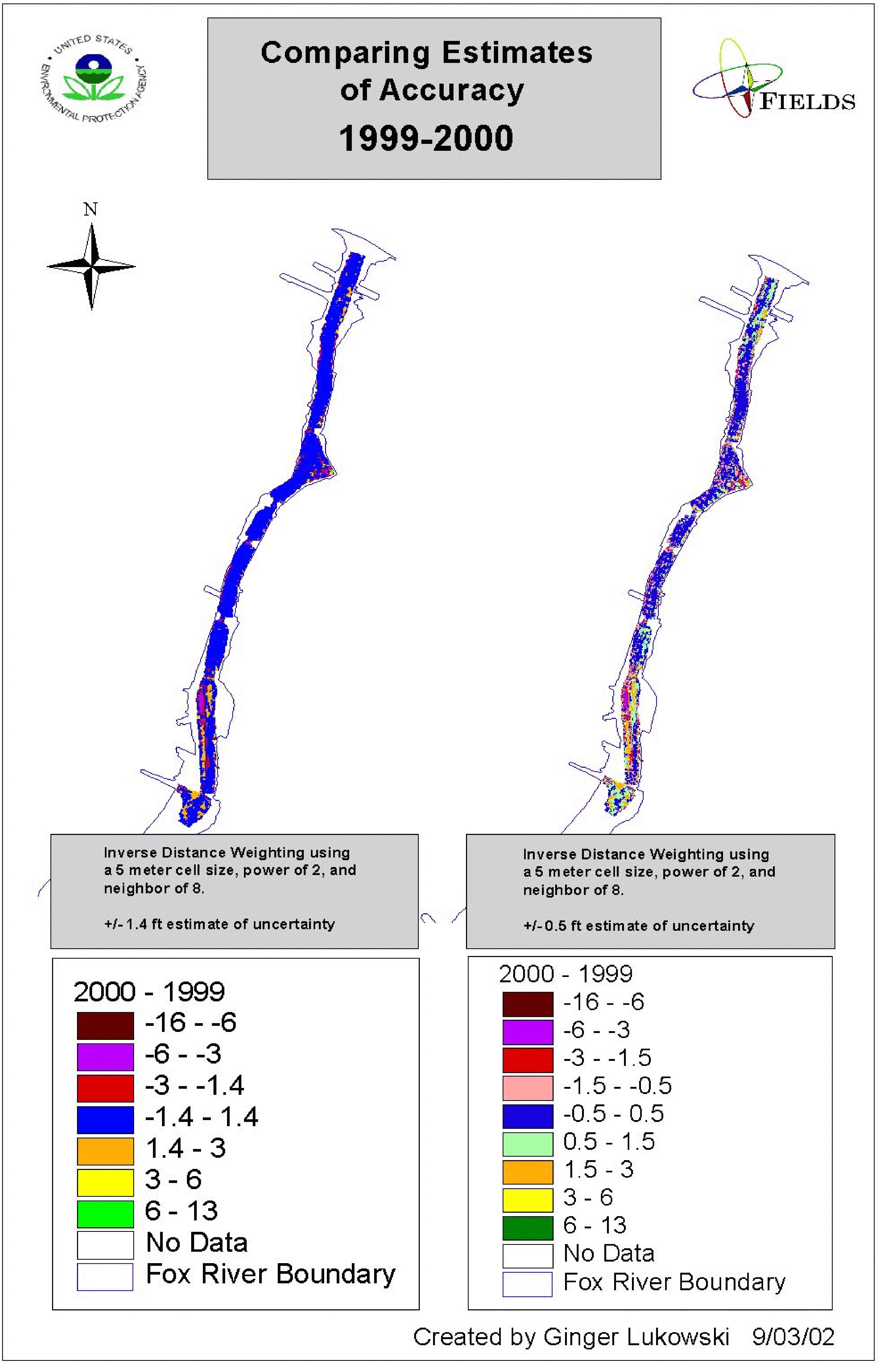

Comparing Estimates
of Accuracy
1999-2000
FIELDS
N
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 0.5 ft estimate of uncertainty
2000 - 1999
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
2000 - 1999
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

**Figure 14f**

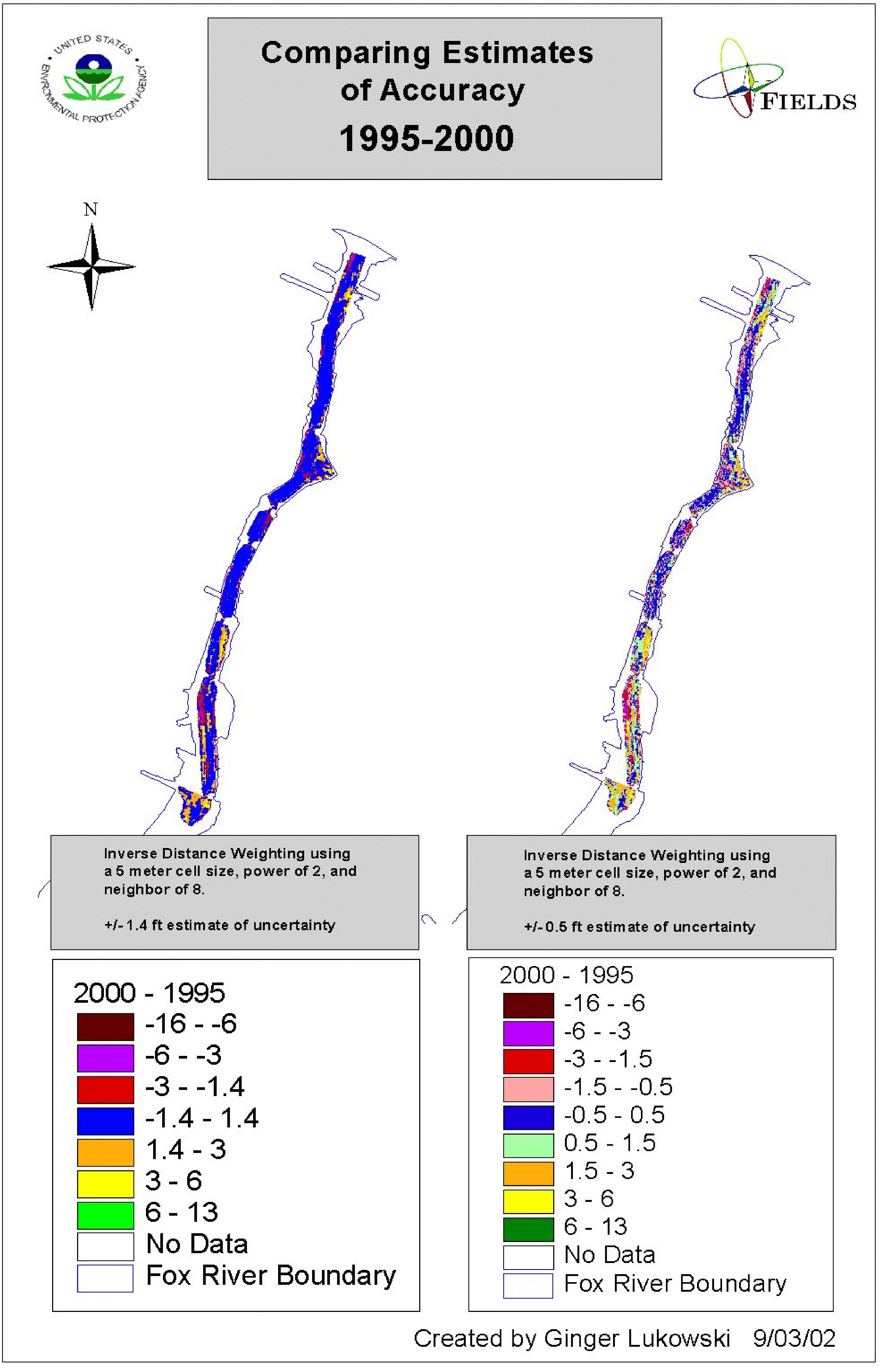

Comparing Estimates
of Accuracy
1995-2000
N
FIELDS
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 1.4 ft estimate of uncertainty
Inverse Distance Weighting using
a 5 meter cell size, power of 2, and
neighbor of 8.
+/- 0.5 ft estimate of uncertainty
2000 - 1995
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
2000 - 1995
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
Created by Ginger Lukowski 9/03/02

Figure 15a

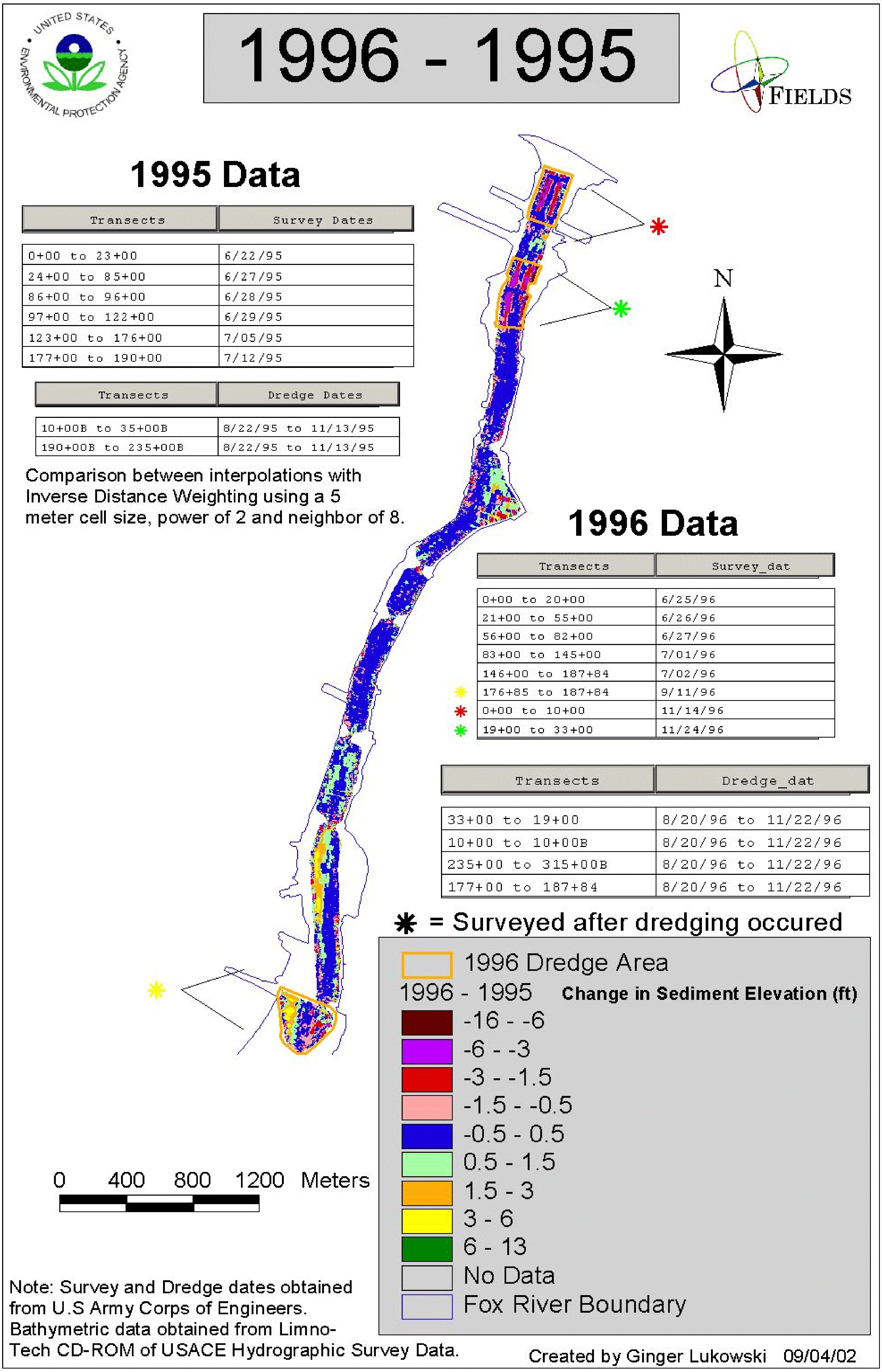
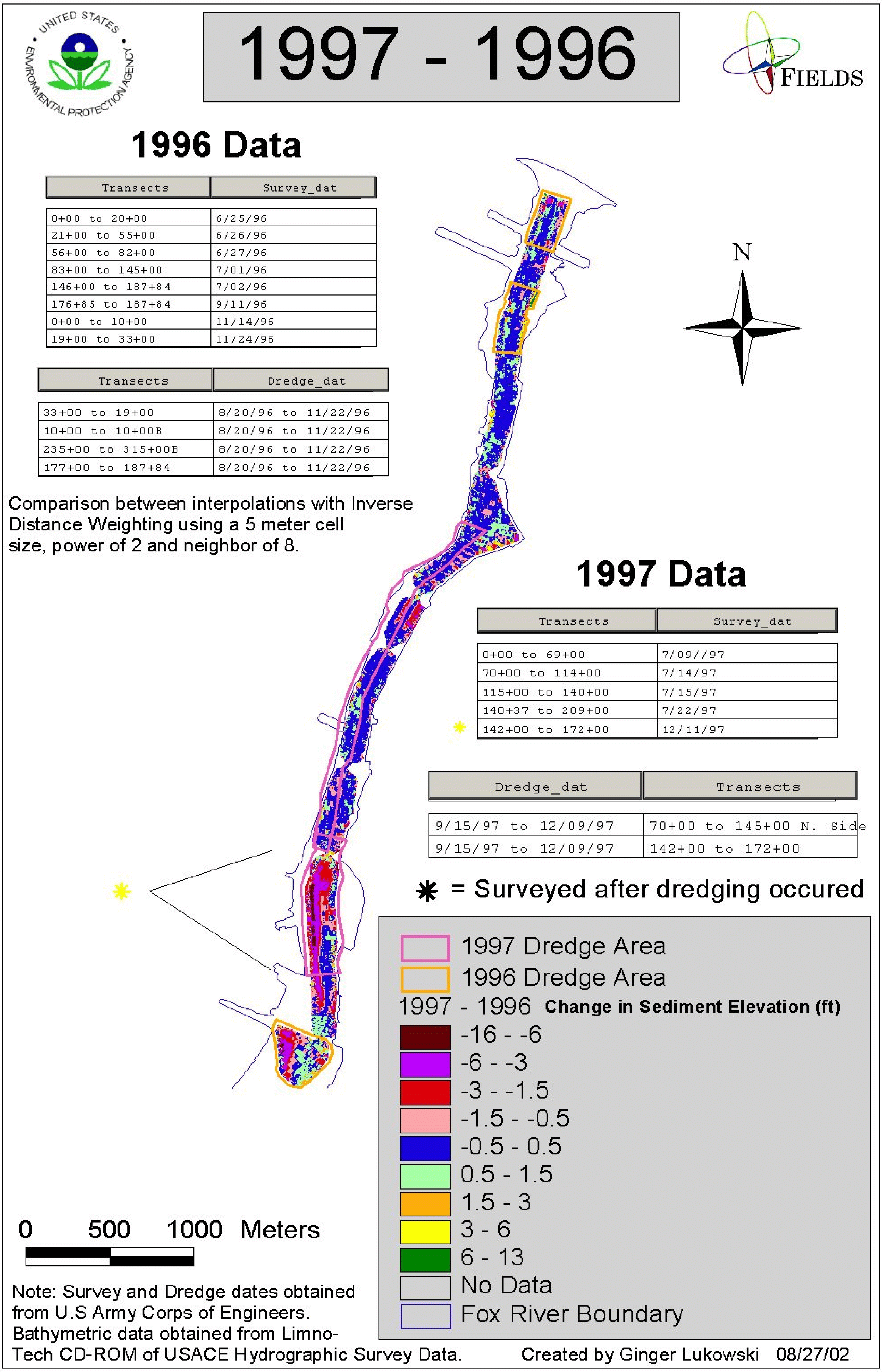

1996 - 1995
FIELDS
1995 Data
Transects | Survey Dates
0+00 to 23+00 | 6/22/95
24+00 to 85+00 | 6/27/95
86+00 to 96+00 | 6/28/95
97+00 to 122+00 | 6/29/95
123+00 to 176+00 | 7/05/95
177+00 to 190+00 | 7/12/95
Transects | Dredge Dates
10+00B to 35+00B | 8/22/95 to 11/13/95
190+00B to 235+00B | 8/22/95 to 11/13/95
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
N
1996 Data
Transects | Survey_dat
0+00 to 20+00 | 6/25/96
21+00 to 55+00 | 6/26/96
56+00 to 82+00 | 6/27/96
83+00 to 145+00 | 7/01/96
146+00 to 187+84 | 7/02/96
* 176+85 to 187+84 | 9/11/96
* 0+00 to 10+00 | 11/14/96
* 19+00 to 33+00 | 11/24/96
Transects | Dredge_dat
33+00 to 19+00 | 8/20/96 to 11/22/96
10+00 to 10+00B | 8/20/96 to 11/22/96
235+00 to 315+00B | 8/20/96 to 11/22/96
177+00 to 187+84 | 8/20/96 to 11/22/96
* = Surveyed after dredging occured
1996 Dredge Area
1996 - 1995 Change in Sediment Elevation (ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 400 800 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 09/04/02

**Figure 15b**




**1996 Data**

| Transects | Survey_dat |
|---|---|
| 0+00 to 20+00 | 6/25/96 |
| 21+00 to 55+00 | 6/26/96 |
| 56+00 to 82+00 | 6/27/96 |
| 83+00 to 145+00 | 7/01/96 |
| 146+00 to 187+84 | 7/02/96 |
| 176+85 to 187+84 | 9/11/96 |
| 0+00 to 10+00 | 11/14/96 |
| 19+00 to 33+00 | 11/24/96 |

| Transects | Dredge_dat |
|---|---|
| 33+00 to 19+00 | 8/20/96 to 11/22/96 |
| 10+00 to 10+00B | 8/20/96 to 11/22/96 |
| 235+00 to 315+00B | 8/20/96 to 11/22/96 |
| 177+00 to 187+84 | 8/20/96 to 11/22/96 |

**1997 Data**

| Transects | Survey_dat |
|---|---|
| 0+00 to 69+00 | 7/09//97 |
| 70+00 to 114+00 | 7/14/97 |
| 115+00 to 140+00 | 7/15/97 |
| 140+37 to 209+00 | 7/22/97 |
| * 142+00 to 172+00 | 12/11/97 |

| Dredge_dat | Transects |
|---|---|
| 9/15/97 to 12/09/97 | 70+00 to 145+00 N. Side |
| 9/15/97 to 12/09/97 | 142+00 to 172+00 |

**Figure 15c**

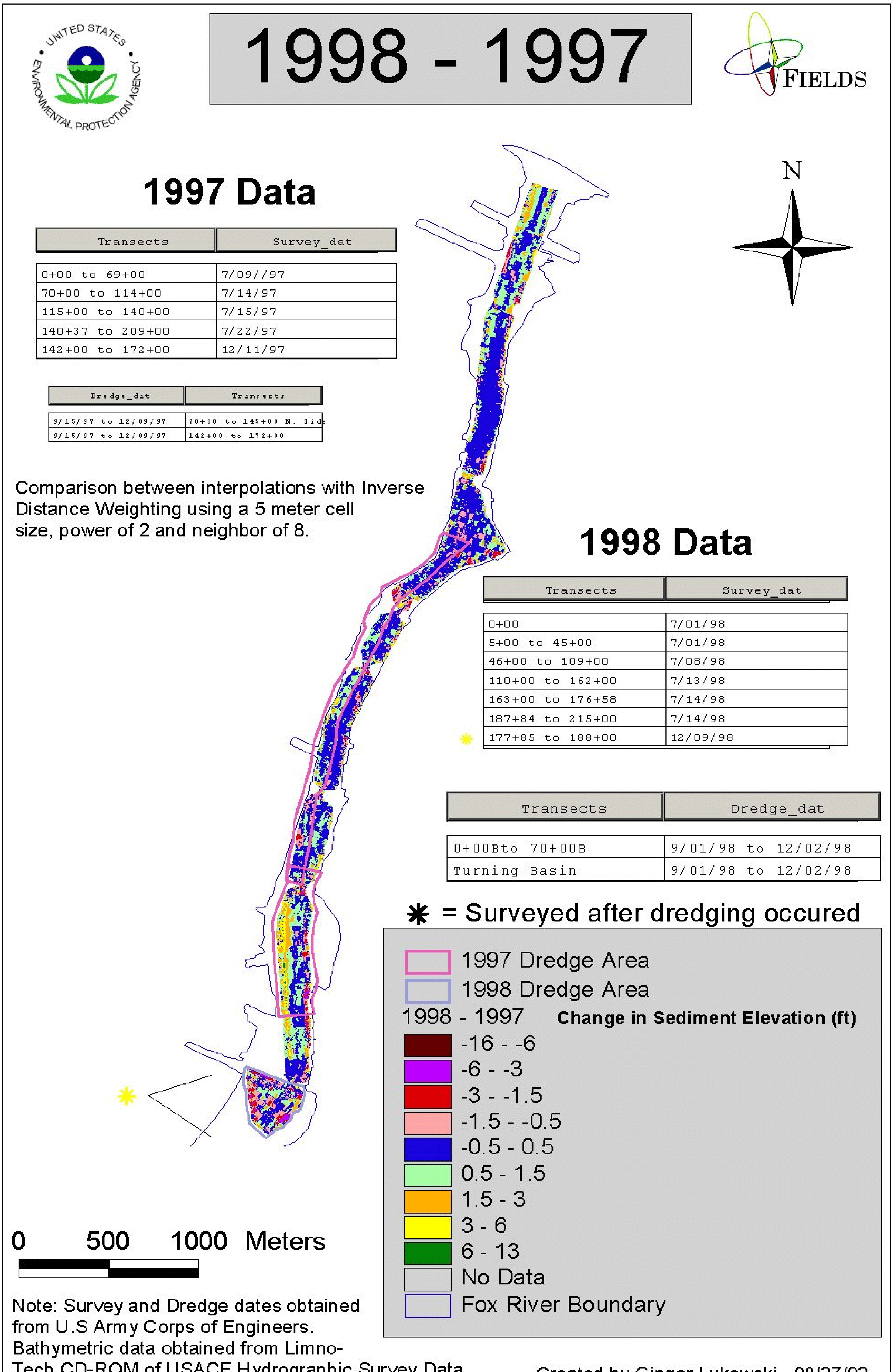

1998 - 1997
FIELDS
N
1997 Data
Transects | Survey_dat
0+00 to 69+00 | 7/09//97
70+00 to 114+00 | 7/14/97
115+00 to 140+00 | 7/15/97
140+37 to 209+00 | 7/22/97
142+00 to 172+00 | 12/11/97
Dredge_dat | Transects
9/15/97 to 12/09/97 | 70+00 to 145+00 N. Side
9/15/97 to 12/09/97 | 142+00 to 172+00
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
1998 Data
Transects | Survey_dat
0+00 | 7/01/98
5+00 to 45+00 | 7/01/98
46+00 to 109+00 | 7/08/98
110+00 to 162+00 | 7/13/98
163+00 to 176+58 | 7/14/98
187+84 to 215+00 | 7/14/98
177+85 to 188+00 | 12/09/98
Transects | Dredge_dat
0+00Bto 70+00B | 9/01/98 to 12/02/98
Turning Basin | 9/01/98 to 12/02/98
* = Surveyed after dredging occured
1997 Dredge Area
1998 Dredge Area
1998 - 1997 Change in Sediment Elevation (ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 500 1000 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 08/27/02

**Figure 15d**

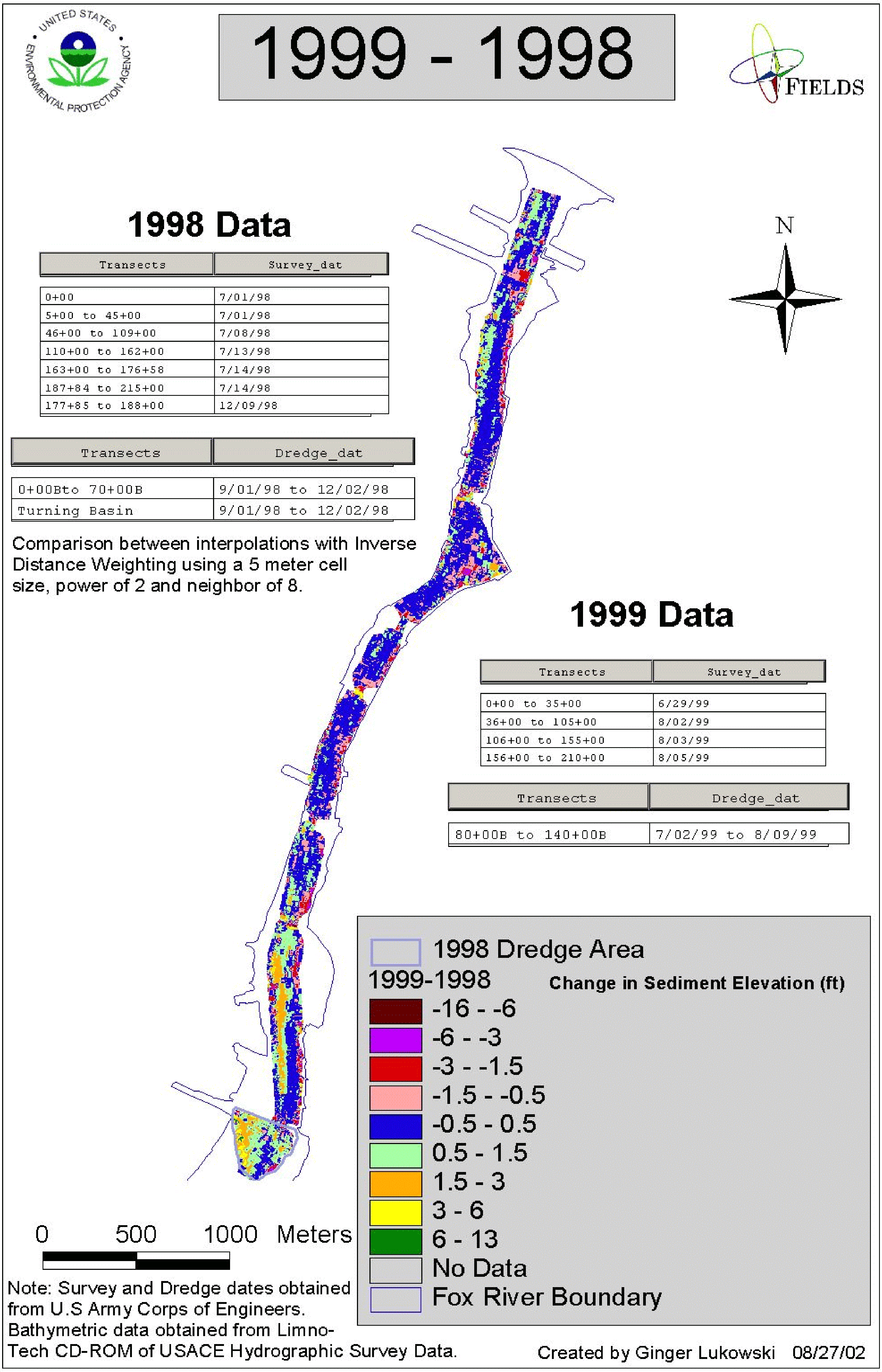

1999 - 1998
FIELDS
N
1998 Data
Transects | Survey_dat
0+00 | 7/01/98
5+00 to 45+00 | 7/01/98
46+00 to 109+00 | 7/08/98
110+00 to 162+00 | 7/13/98
163+00 to 176+58 | 7/14/98
187+84 to 215+00 | 7/14/98
177+85 to 188+00 | 12/09/98
Transects | Dredge_dat
0+00Bto 70+00B | 9/01/98 to 12/02/98
Turning Basin | 9/01/98 to 12/02/98
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
1999 Data
Transects | Survey_dat
0+00 to 35+00 | 6/29/99
36+00 to 105+00 | 8/02/99
106+00 to 155+00 | 8/03/99
156+00 to 210+00 | 8/05/99
Transects | Dredge_dat
80+00B to 140+00B | 7/02/99 to 8/09/99
1998 Dredge Area
1999-1998
Change in Sediment Elevation (ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 500 1000 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 08/27/02

**Figure 15e**

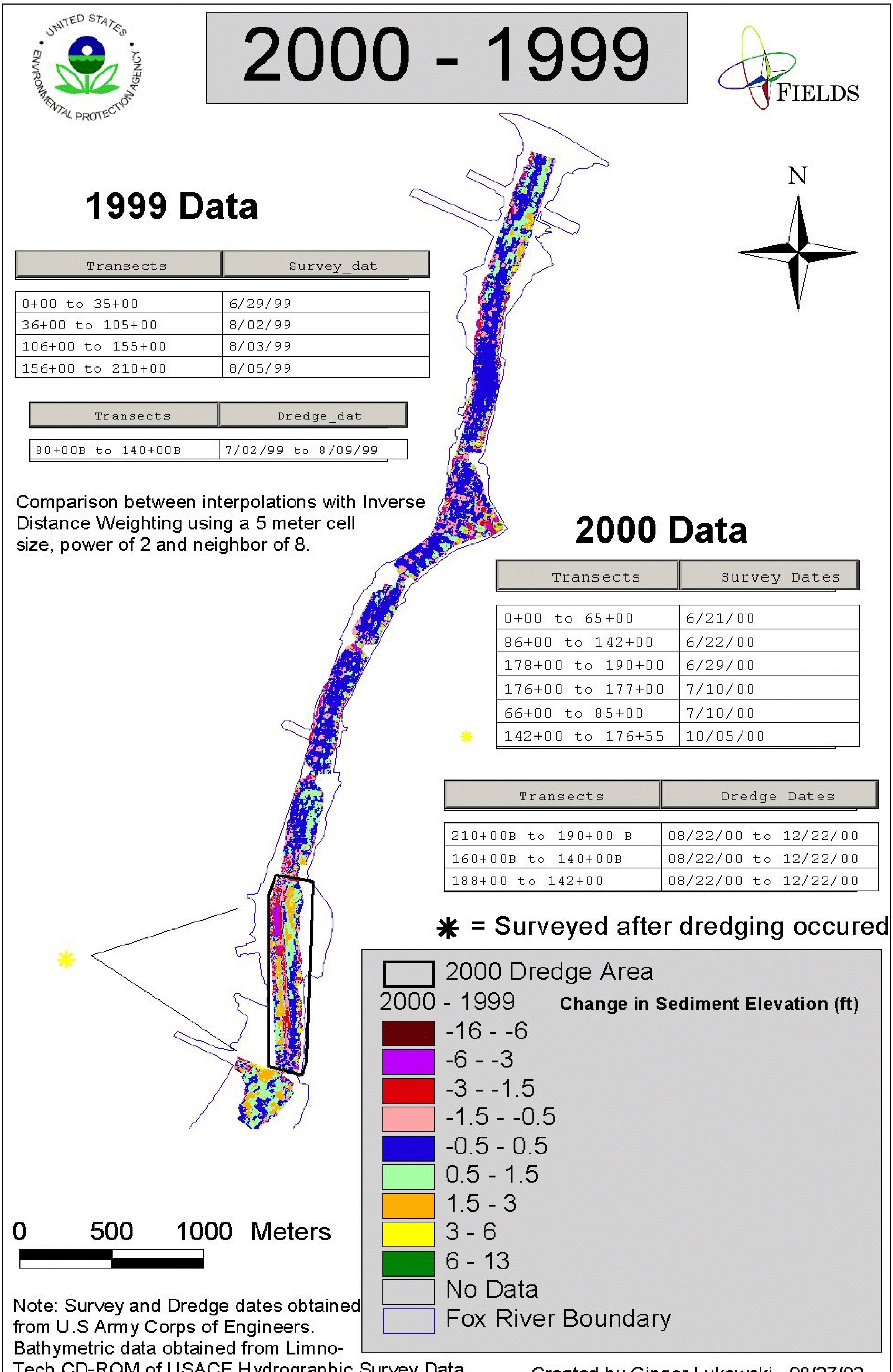

2000 - 1999
FIELDS
N
1999 Data
Transects | Survey_dat
0+00 to 35+00 | 6/29/99
36+00 to 105+00 | 8/02/99
106+00 to 155+00 | 8/03/99
156+00 to 210+00 | 8/05/99
Transects | Dredge_dat
80+00B to 140+00B | 7/02/99 to 8/09/99
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
2000 Data
Transects | Survey Dates
0+00 to 65+00 | 6/21/00
86+00 to 142+00 | 6/22/00
178+00 to 190+00 | 6/29/00
176+00 to 177+00 | 7/10/00
66+00 to 85+00 | 7/10/00
142+00 to 176+55 | 10/05/00
Transects | Dredge Dates
210+00B to 190+00 B | 08/22/00 to 12/22/00
160+00B to 140+00B | 08/22/00 to 12/22/00
188+00 to 142+00 | 08/22/00 to 12/22/00
* = Surveyed after dredging occured
2000 Dredge Area
2000 - 1999 Change in Sediment Elevation (ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 500 1000 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 08/27/02

**Figure 15f**

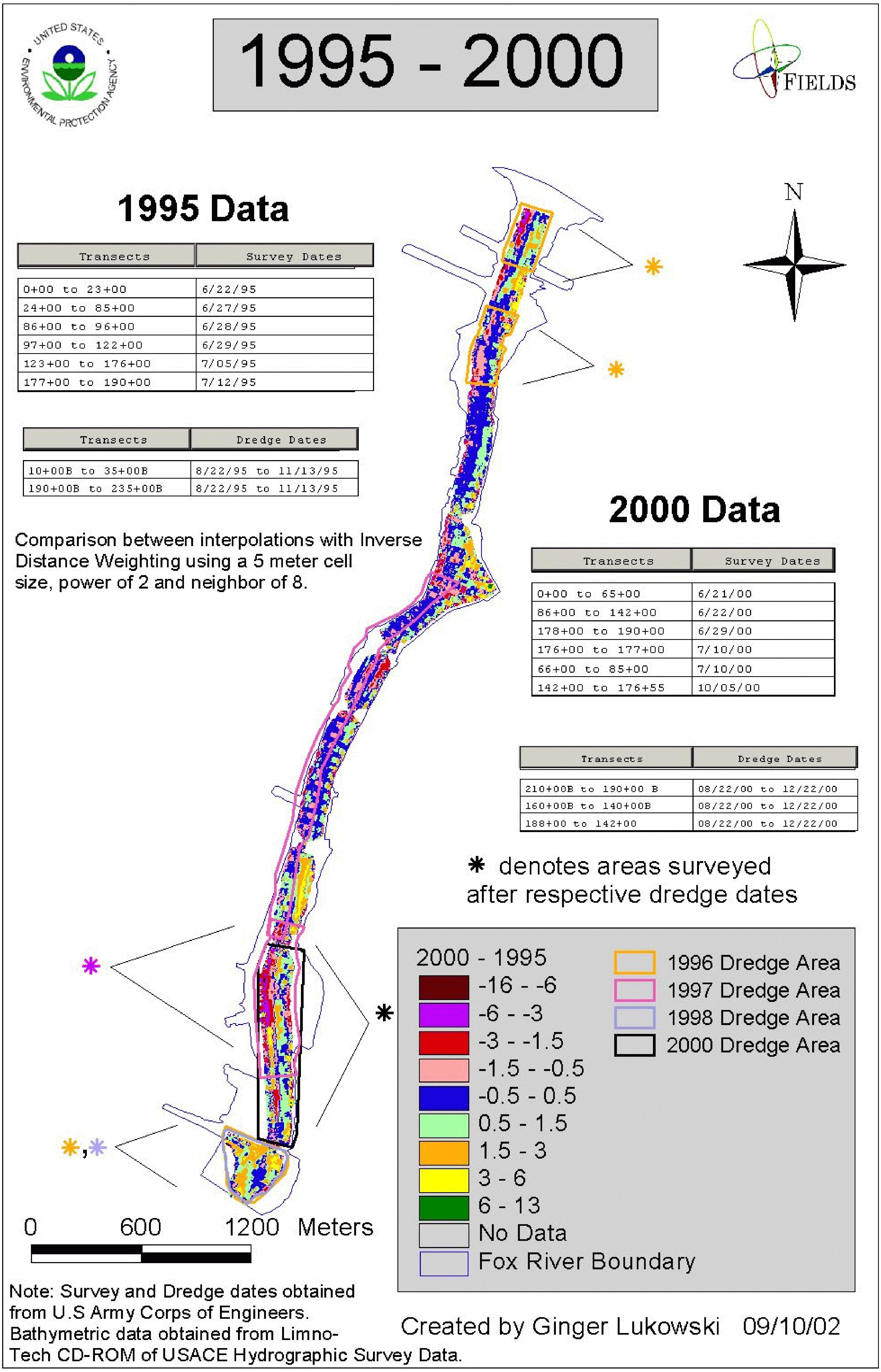
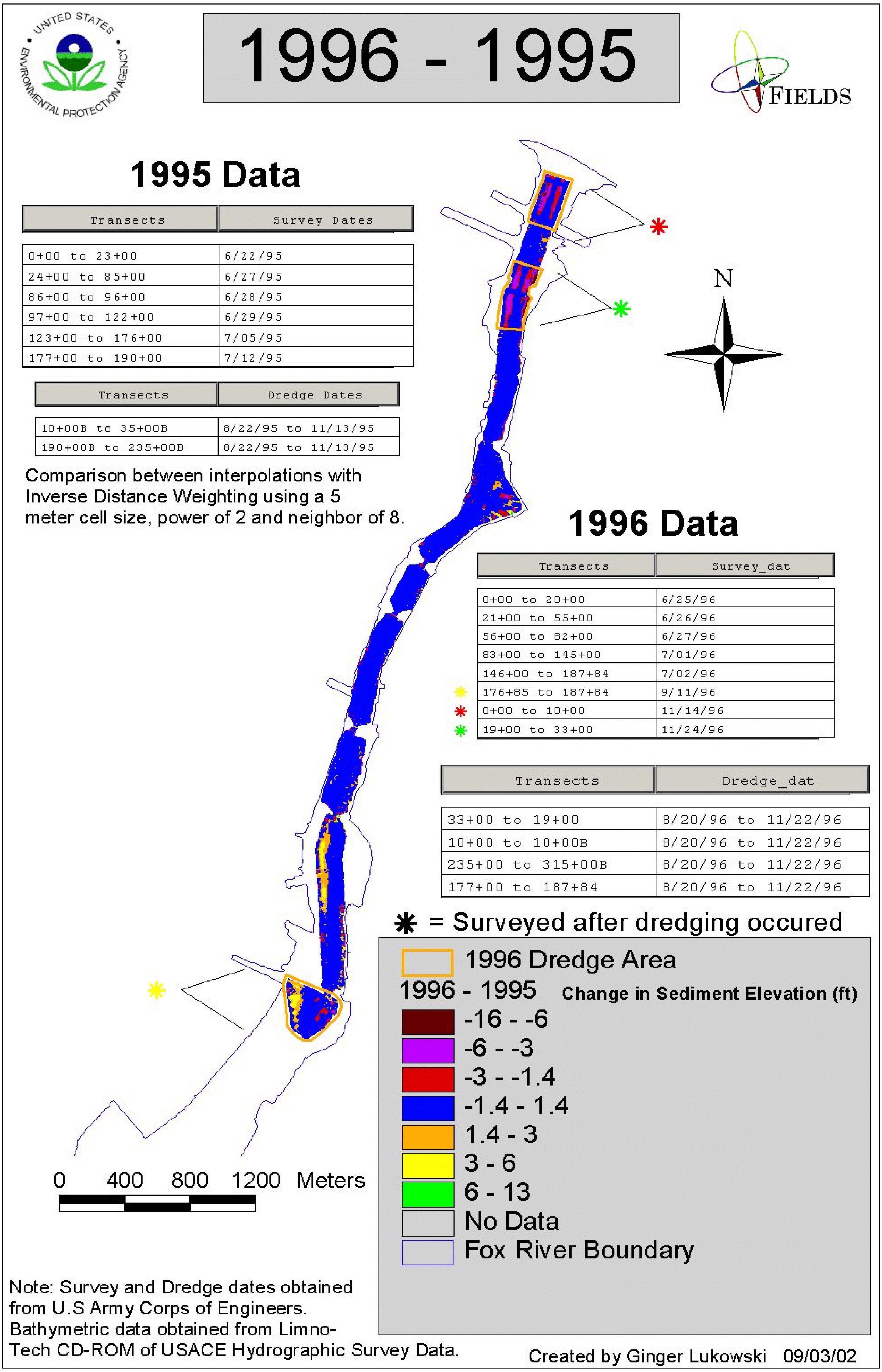

1995 - 2000
FIELDS
N
1995 Data
Transects | Survey Dates
0+00 to 23+00 | 6/22/95
24+00 to 85+00 | 6/27/95
86+00 to 96+00 | 6/28/95
97+00 to 122+00 | 6/29/95
123+00 to 176+00 | 7/05/95
177+00 to 190+00 | 7/12/95
Transects | Dredge Dates
10+00B to 35+00B | 8/22/95 to 11/13/95
190+00B to 235+00B | 8/22/95 to 11/13/95
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
2000 Data
Transects | Survey Dates
0+00 to 65+00 | 6/21/00
86+00 to 142+00 | 6/22/00
178+00 to 190+00 | 6/29/00
176+00 to 177+00 | 7/10/00
66+00 to 85+00 | 7/10/00
142+00 to 176+55 | 10/05/00
Transects | Dredge Dates
210+00B to 190+00 B | 08/22/00 to 12/22/00
160+00B to 140+00B | 08/22/00 to 12/22/00
188+00 to 142+00 | 08/22/00 to 12/22/00
* denotes areas surveyed after respective dredge dates
2000 - 1995
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
1996 Dredge Area
1997 Dredge Area
1998 Dredge Area
2000 Dredge Area
0 600 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 09/10/02

**Figure 16a**



1996 - 1995
FIELDS
1995 Data
Transects | Survey Dates
0+00 to 23+00 | 6/22/95
24+00 to 85+00 | 6/27/95
86+00 to 96+00 | 6/28/95
97+00 to 122+00 | 6/29/95
123+00 to 176+00 | 7/05/95
177+00 to 190+00 | 7/12/95
Transects | Dredge Dates
10+00B to 35+00B | 8/22/95 to 11/13/95
190+00B to 235+00B | 8/22/95 to 11/13/95
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
N
1996 Data
Transects | Survey_dat
0+00 to 20+00 | 6/25/96
21+00 to 55+00 | 6/26/96
56+00 to 82+00 | 6/27/96
83+00 to 145+00 | 7/01/96
146+00 to 187+84 | 7/02/96
* 176+85 to 187+84 | 9/11/96
* 0+00 to 10+00 | 11/14/96
* 19+00 to 33+00 | 11/24/96
Transects | Dredge_dat
33+00 to 19+00 | 8/20/96 to 11/22/96
10+00 to 10+00B | 8/20/96 to 11/22/96
235+00 to 315+00B | 8/20/96 to 11/22/96
177+00 to 187+84 | 8/20/96 to 11/22/96
* = Surveyed after dredging occured
1996 Dredge Area
1996 - 1995 Change in Sediment Elevation (ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 400 800 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 09/03/02

Figure 16b

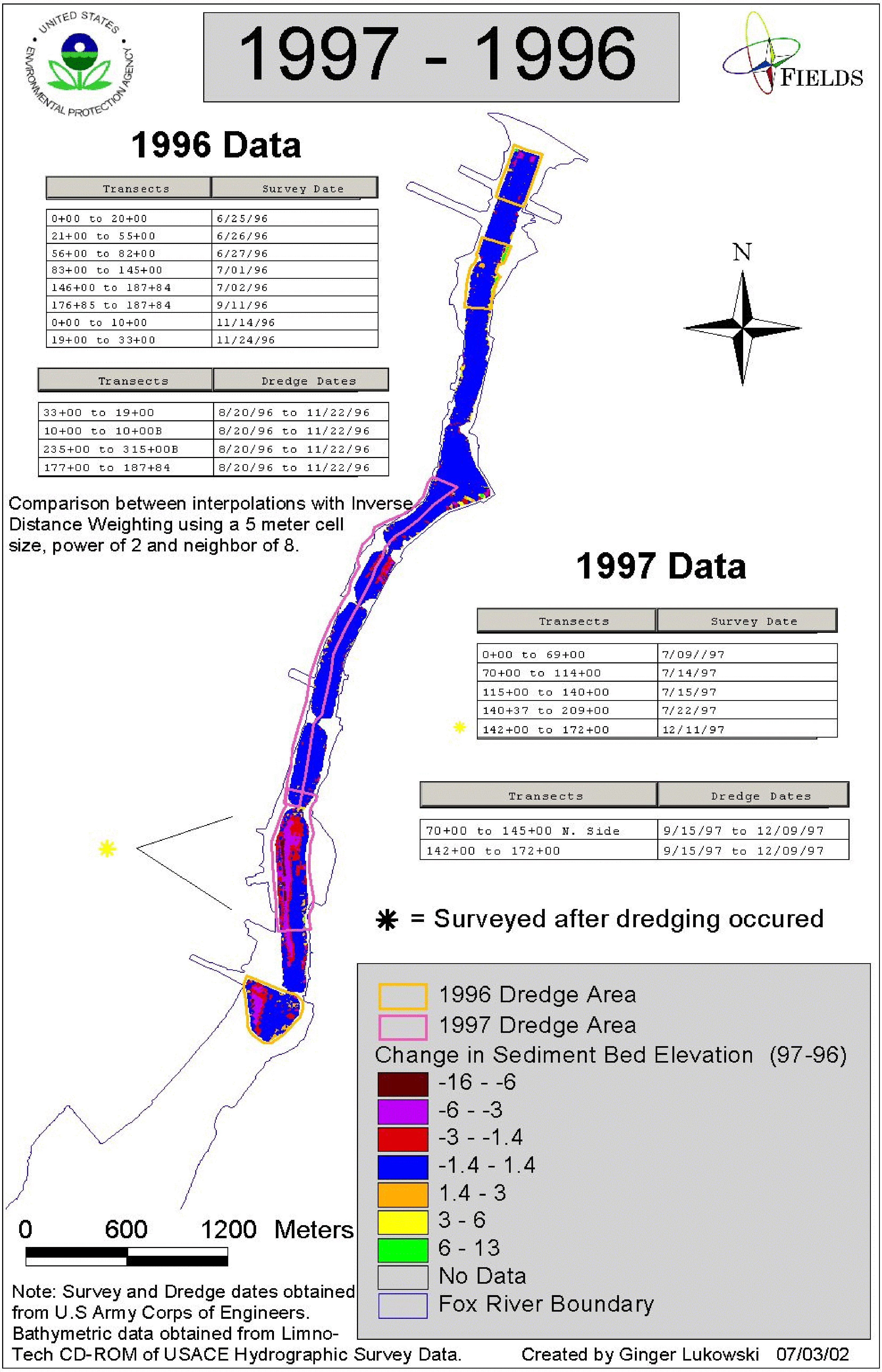

1997 - 1996
FIELDS
1996 Data
Transects | Survey Date
0+00 to 20+00 | 6/25/96
21+00 to 55+00 | 6/26/96
56+00 to 82+00 | 6/27/96
83+00 to 145+00 | 7/01/96
146+00 to 187+84 | 7/02/96
176+85 to 187+84 | 9/11/96
0+00 to 10+00 | 11/14/96
19+00 to 33+00 | 11/24/96
Transects | Dredge Dates
33+00 to 19+00 | 8/20/96 to 11/22/96
10+00 to 10+00B | 8/20/96 to 11/22/96
235+00 to 315+00B | 8/20/96 to 11/22/96
177+00 to 187+84 | 8/20/96 to 11/22/96
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
N
1997 Data
Transects | Survey Date
0+00 to 69+00 | 7/09//97
70+00 to 114+00 | 7/14/97
115+00 to 140+00 | 7/15/97
140+37 to 209+00 | 7/22/97
142+00 to 172+00 | 12/11/97
Transects | Dredge Dates
70+00 to 145+00 N. Side | 9/15/97 to 12/09/97
142+00 to 172+00 | 9/15/97 to 12/09/97
* = Surveyed after dredging occured
1996 Dredge Area
1997 Dredge Area
Change in Sediment Bed Elevation (97-96)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 600 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 07/03/02

**Figure 16c**

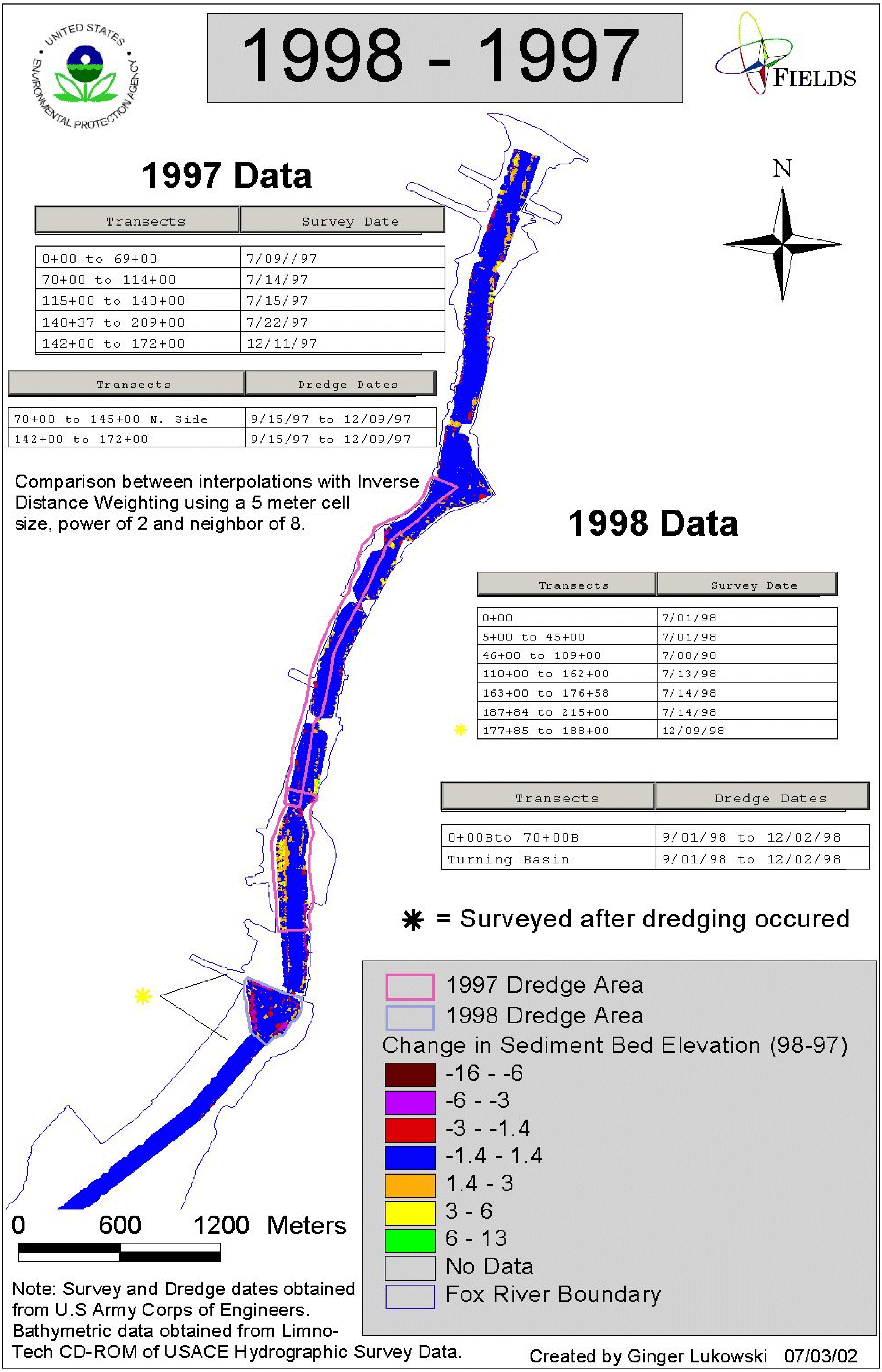
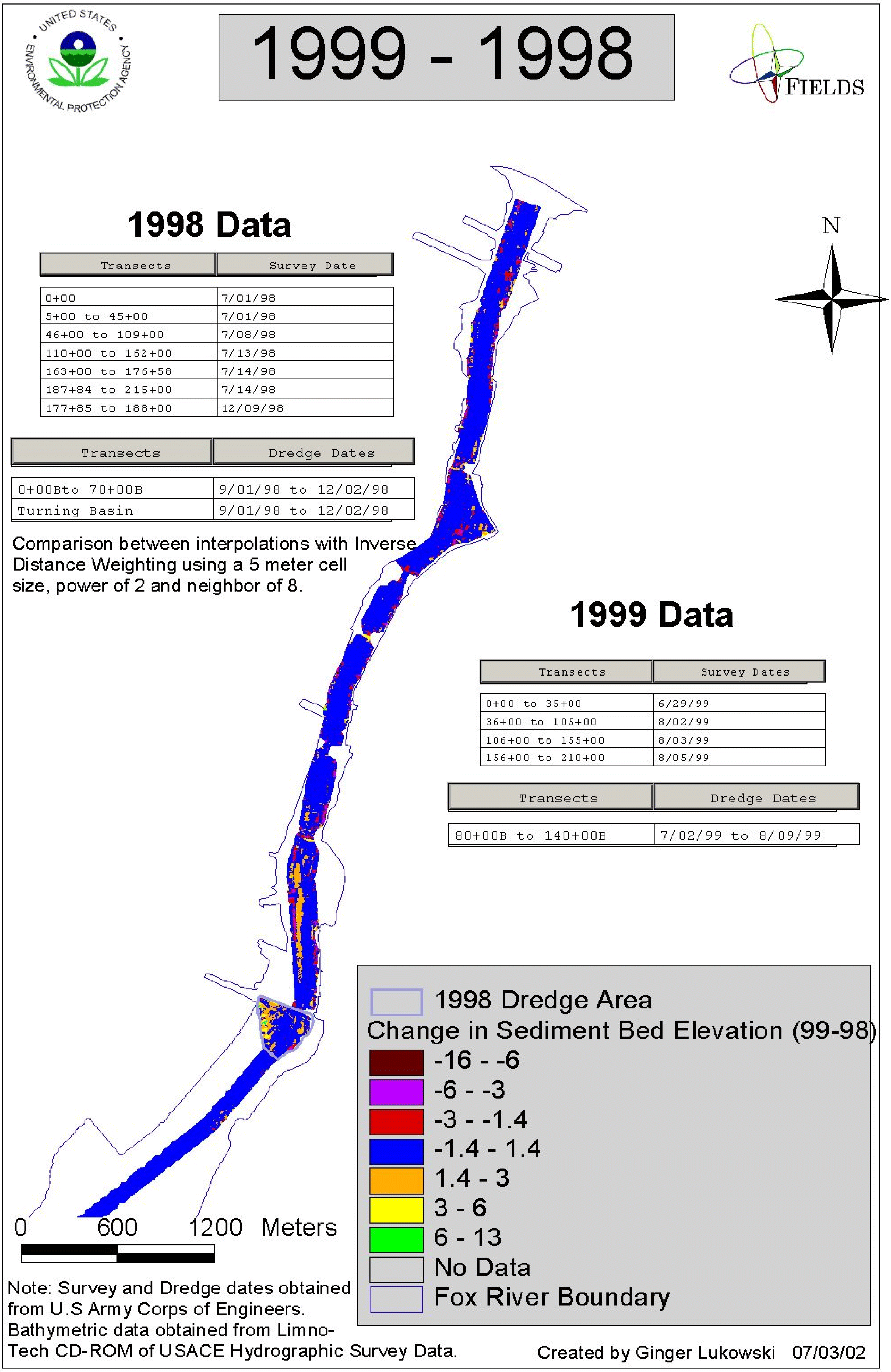
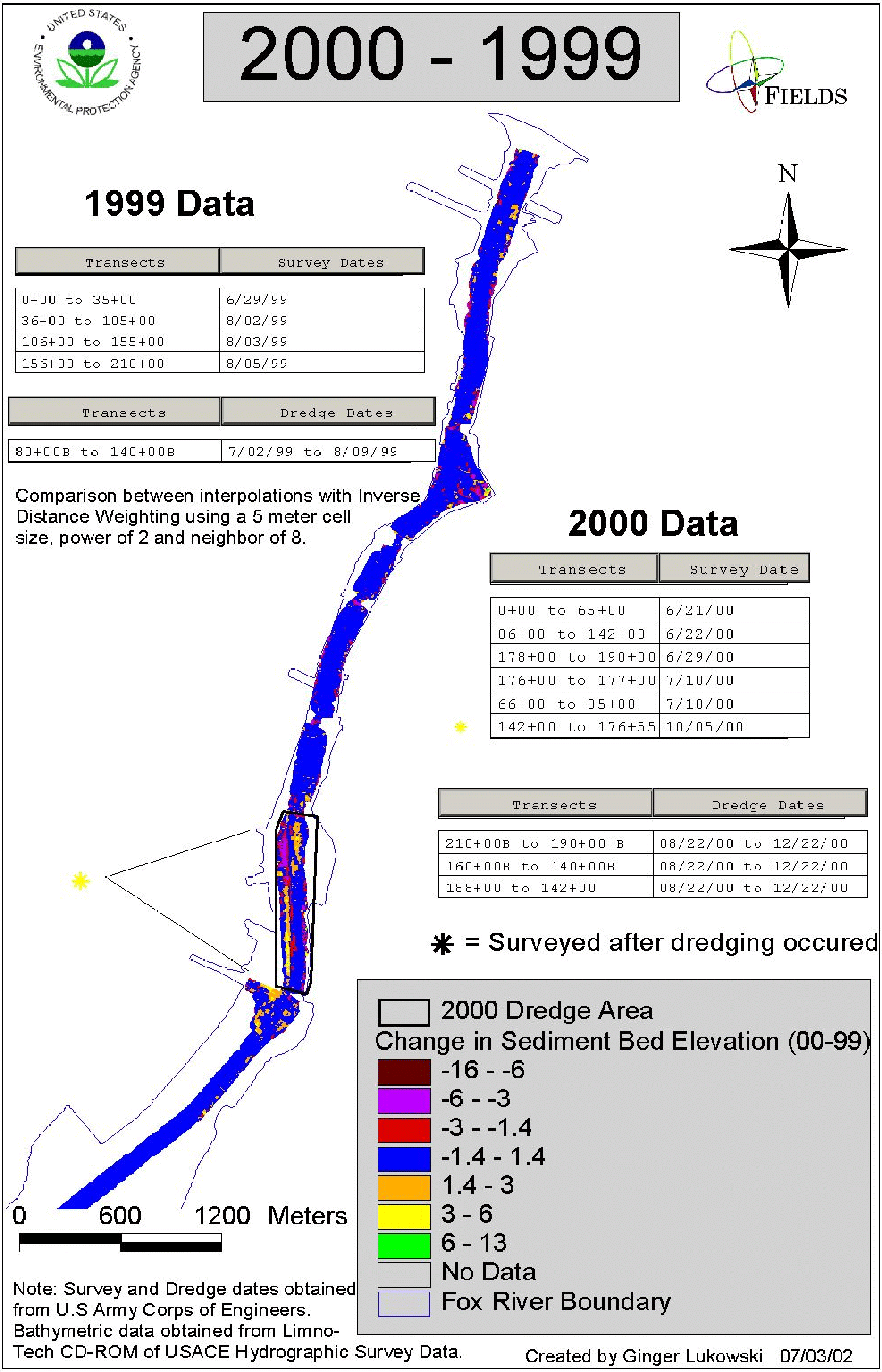

1998 - 1997
FIELDS
N
1997 Data
Transects | Survey Date
0+00 to 69+00 | 7/09//97
70+00 to 114+00 | 7/14/97
115+00 to 140+00 | 7/15/97
140+37 to 209+00 | 7/22/97
142+00 to 172+00 | 12/11/97
Transects | Dredge Dates
70+00 to 145+00 N. Side | 9/15/97 to 12/09/97
142+00 to 172+00 | 9/15/97 to 12/09/97
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
1998 Data
Transects | Survey Date
0+00 | 7/01/98
5+00 to 45+00 | 7/01/98
46+00 to 109+00 | 7/08/98
110+00 to 162+00 | 7/13/98
163+00 to 176+58 | 7/14/98
187+84 to 215+00 | 7/14/98
177+85 to 188+00 | 12/09/98
Transects | Dredge Dates
0+00Bto 70+00B | 9/01/98 to 12/02/98
Turning Basin | 9/01/98 to 12/02/98
* = Surveyed after dredging occured
1997 Dredge Area
1998 Dredge Area
Change in Sediment Bed Elevation (98-97)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 600 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 07/03/02

**Figure 16d**



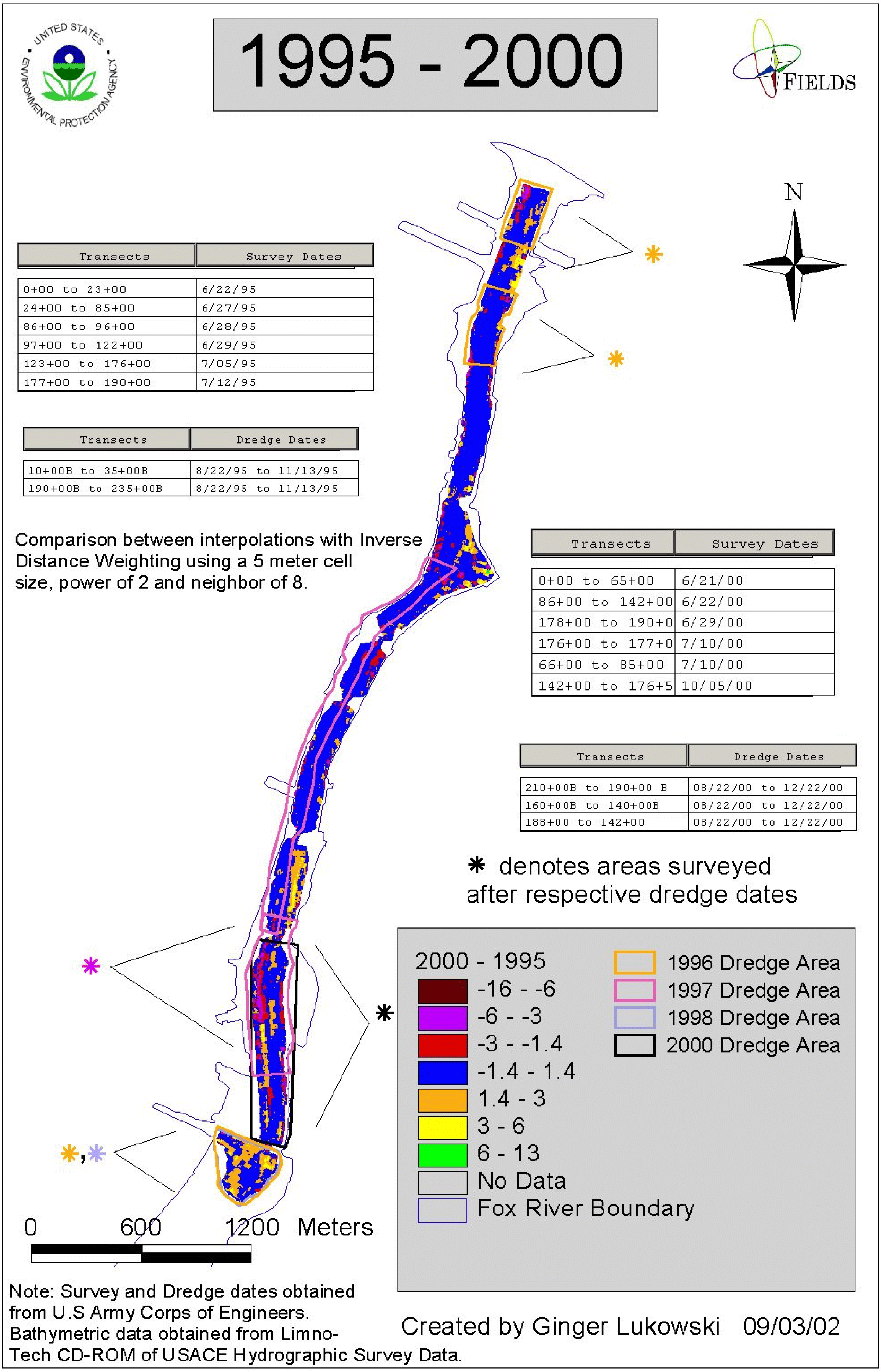
1999 - 1998
FIELDS
1998 Data
Transects | Survey Date
0+00 | 7/01/98
5+00 to 45+00 | 7/01/98
46+00 to 109+00 | 7/08/98
110+00 to 162+00 | 7/13/98
163+00 to 176+58 | 7/14/98
187+84 to 215+00 | 7/14/98
177+85 to 188+00 | 12/09/98
Transects | Dredge Dates
0+00Bto 70+00B | 9/01/98 to 12/02/98
Turning Basin | 9/01/98 to 12/02/98
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
N
1999 Data
Transects | Survey Dates
0+00 to 35+00 | 6/29/99
36+00 to 105+00 | 8/02/99
106+00 to 155+00 | 8/03/99
156+00 to 210+00 | 8/05/99
Transects | Dredge Dates
80+00B to 140+00B | 7/02/99 to 8/09/99
1998 Dredge Area
Change in Sediment Bed Elevation (99-98)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 600 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 07/03/02

Figure 16e



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
2000 - 1999
FIELDS
N
1999 Data
Transects | Survey Dates
0+00 to 35+00 | 6/29/99
36+00 to 105+00 | 8/02/99
106+00 to 155+00 | 8/03/99
156+00 to 210+00 | 8/05/99
Transects | Dredge Dates
80+00B to 140+00B | 7/02/99 to 8/09/99
Comparison between interpolations with Inverse Distance Weighting using a 5 meter cell size, power of 2 and neighbor of 8.
2000 Data
Transects | Survey Date
0+00 to 65+00 | 6/21/00
86+00 to 142+00 | 6/22/00
178+00 to 190+00 | 6/29/00
176+00 to 177+00 | 7/10/00
66+00 to 85+00 | 7/10/00
142+00 to 176+55 | 10/05/00
Transects | Dredge Dates
210+00B to 190+00 B | 08/22/00 to 12/22/00
160+00B to 140+00B | 08/22/00 to 12/22/00
188+00 to 142+00 | 08/22/00 to 12/22/00
* = Surveyed after dredging occured
2000 Dredge Area
Change in Sediment Bed Elevation (00-99)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0 600 1200 Meters
Note: Survey and Dredge dates obtained from U.S Army Corps of Engineers. Bathymetric data obtained from Limno-Tech CD-ROM of USACE Hydrographic Survey Data.
Created by Ginger Lukowski 07/03/02

**Figure 16f**



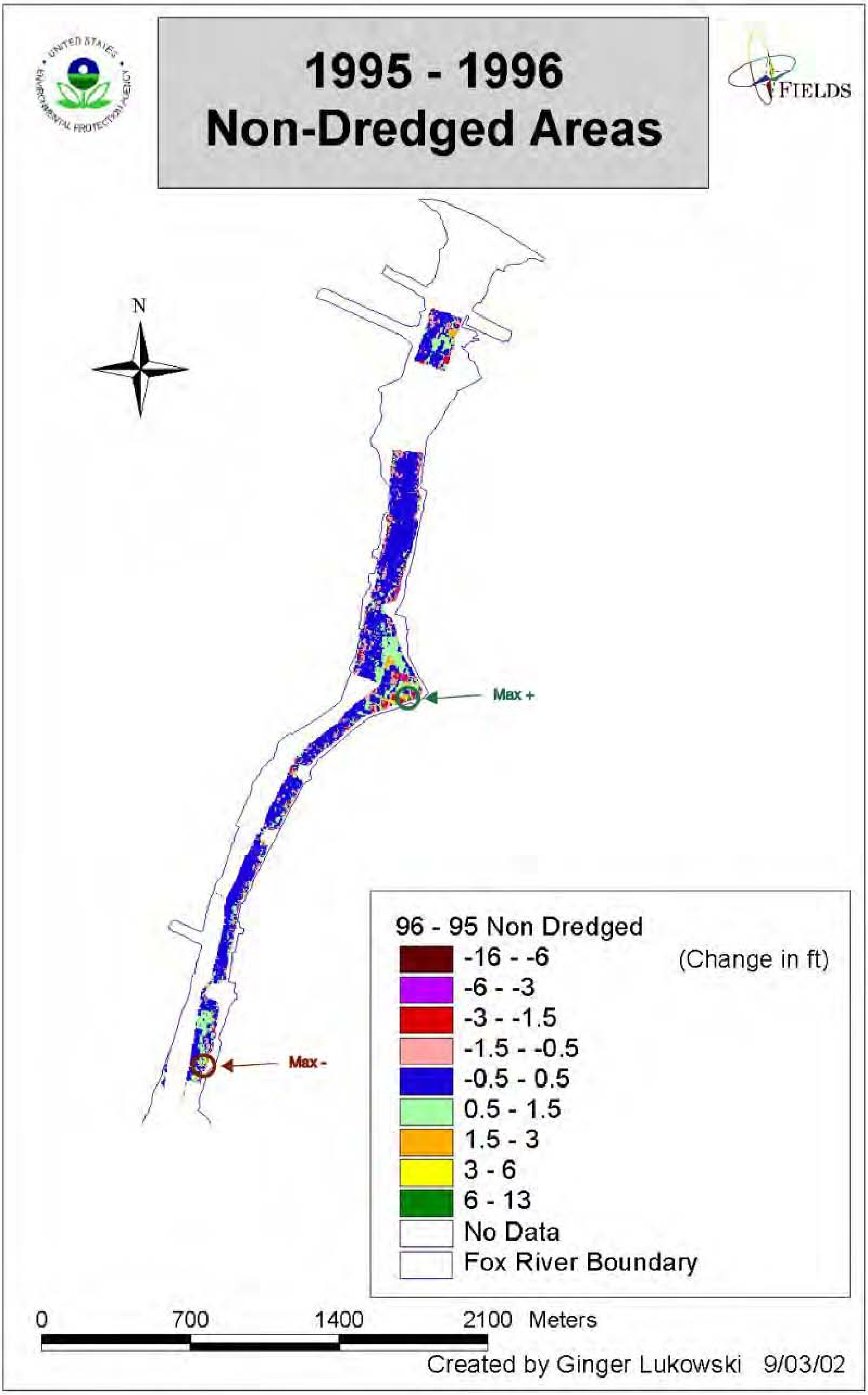

| Transects | Survey Dates |
|---|---|
| 0+00 to 23+00 | 6/22/95 |
| 24+00 to 85+00 | 6/27/95 |
| 86+00 to 96+00 | 6/28/95 |
| 97+00 to 122+00 | 6/29/95 |
| 123+00 to 176+00 | 7/05/95 |
| 177+00 to 190+00 | 7/12/95 |

| Transects | Dredge Dates |
|---|---|
| 10+00B to 35+00B | 8/22/95 to 11/13/95 |
| 190+00B to 235+00B | 8/22/95 to 11/13/95 |

| Transects | Survey Dates |
|---|---|
| 0+00 to 65+00 | 6/21/00 |
| 86+00 to 142+00 | 6/22/00 |
| 178+00 to 190+0 | 6/29/00 |
| 176+00 to 177+0 | 7/10/00 |
| 66+00 to 85+00 | 7/10/00 |
| 142+00 to 176+5 | 10/05/00 |

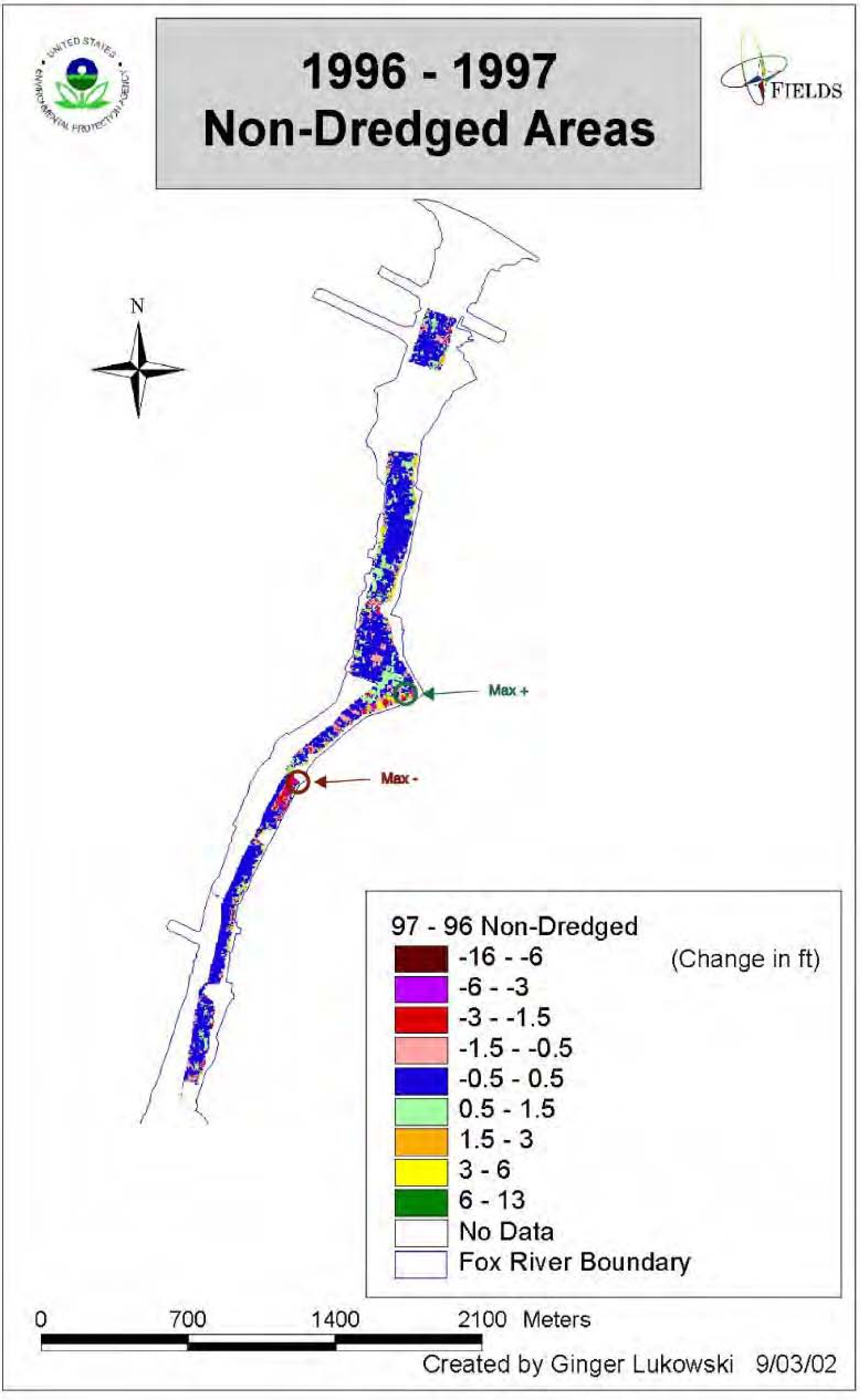
| Transects | Dredge Dates |
|---|---|
| 210+00B to 190+00 B | 08/22/00 to 12/22/00 |
| 160+00B to 140+00B | 08/22/00 to 12/22/00 |
| 188+00 to 142+00 | 08/22/00 to 12/22/00 |

**Figure 17a**



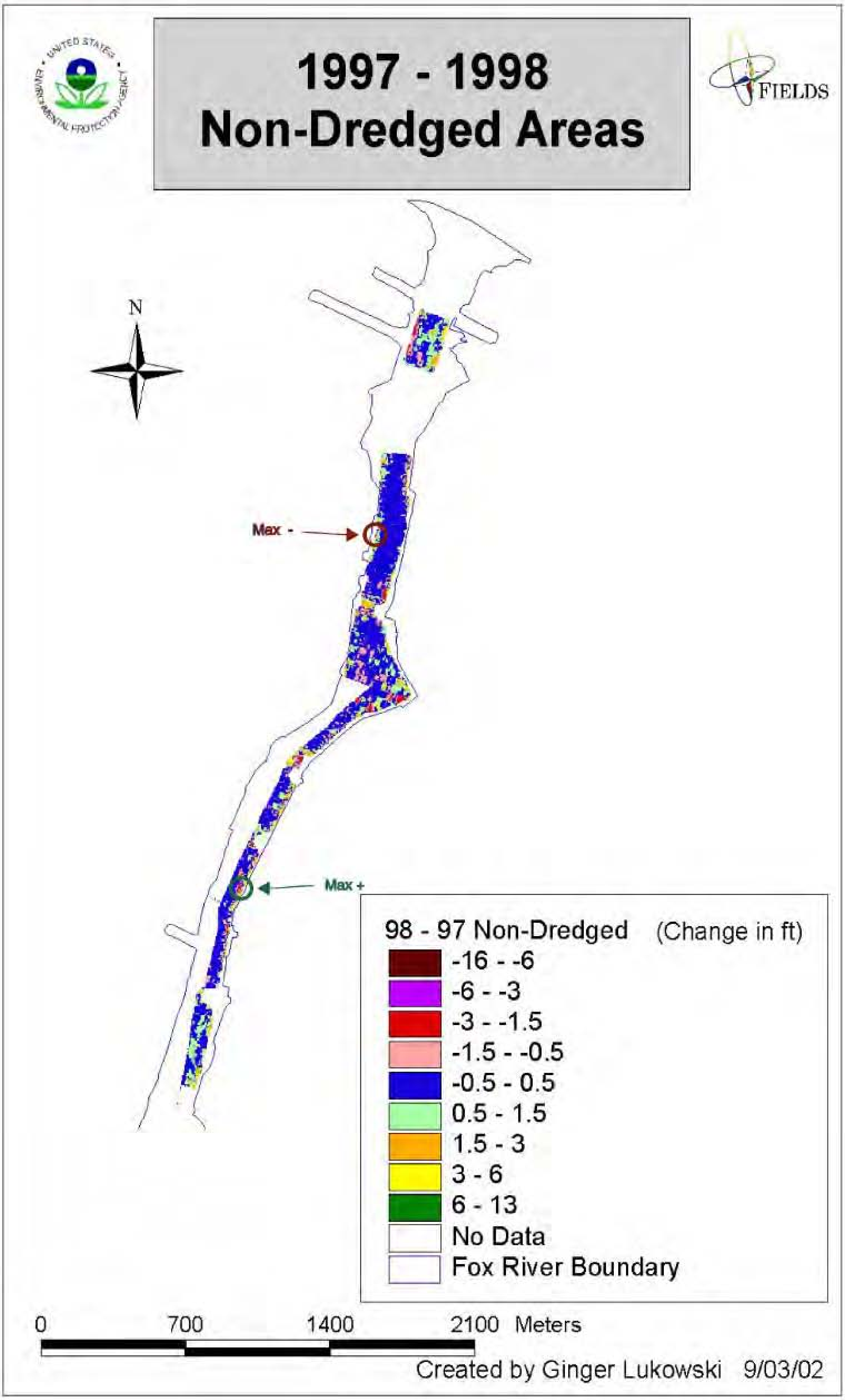
1995 - 1996
Non-Dredged Areas
FIELDS
N
Max +
Max -
96 - 95 Non Dredged
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/03/02

**Figure 17b**



1996 - 1997
Non-Dredged Areas
FIELDS
N
Max +
Max -
97 - 96 Non-Dredged
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/03/02

**Figure 17c**



1997 - 1998
Non-Dredged Areas
FIELDS
N
Max -
Max +
98 - 97 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/03/02

**Figure 17d**

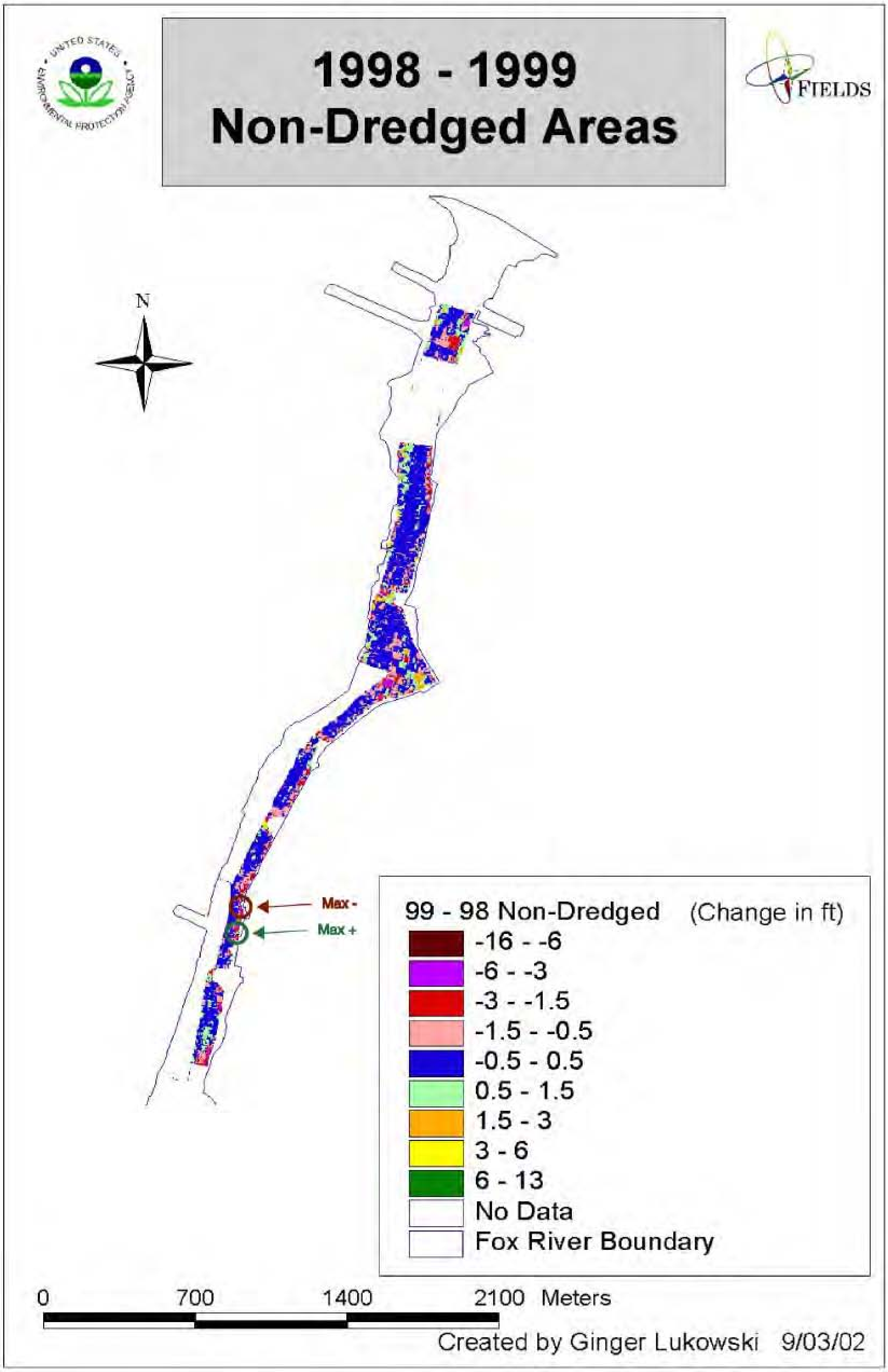
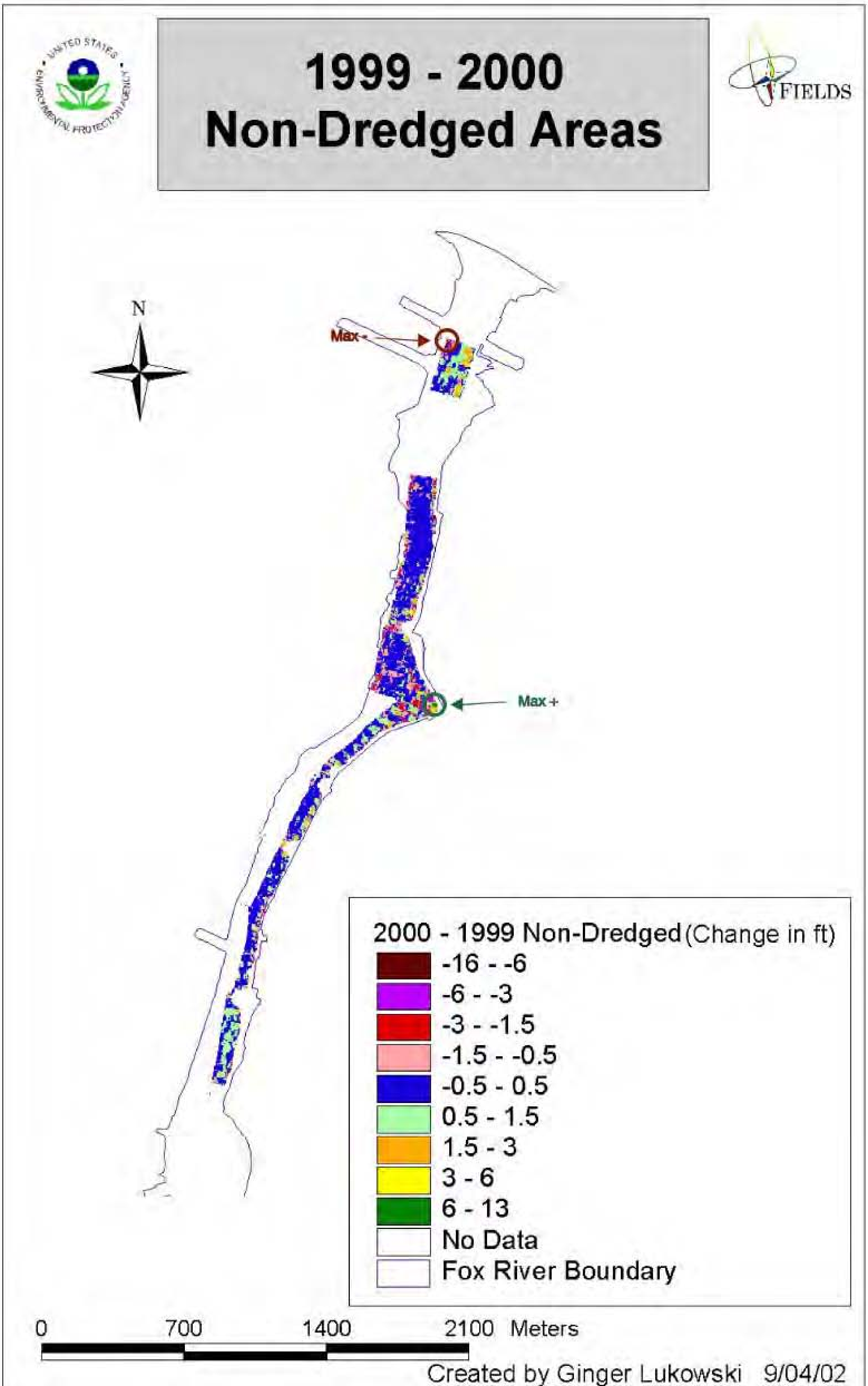

1998 - 1999
Non-Dredged Areas
FIELDS
N
Max -
Max +
99 - 98 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/03/02

**Figure 17e**



1999 - 2000
Non-Dredged Areas
FIELDS
N
Max -
Max +
2000 - 1999 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/04/02

**Figure 17f**

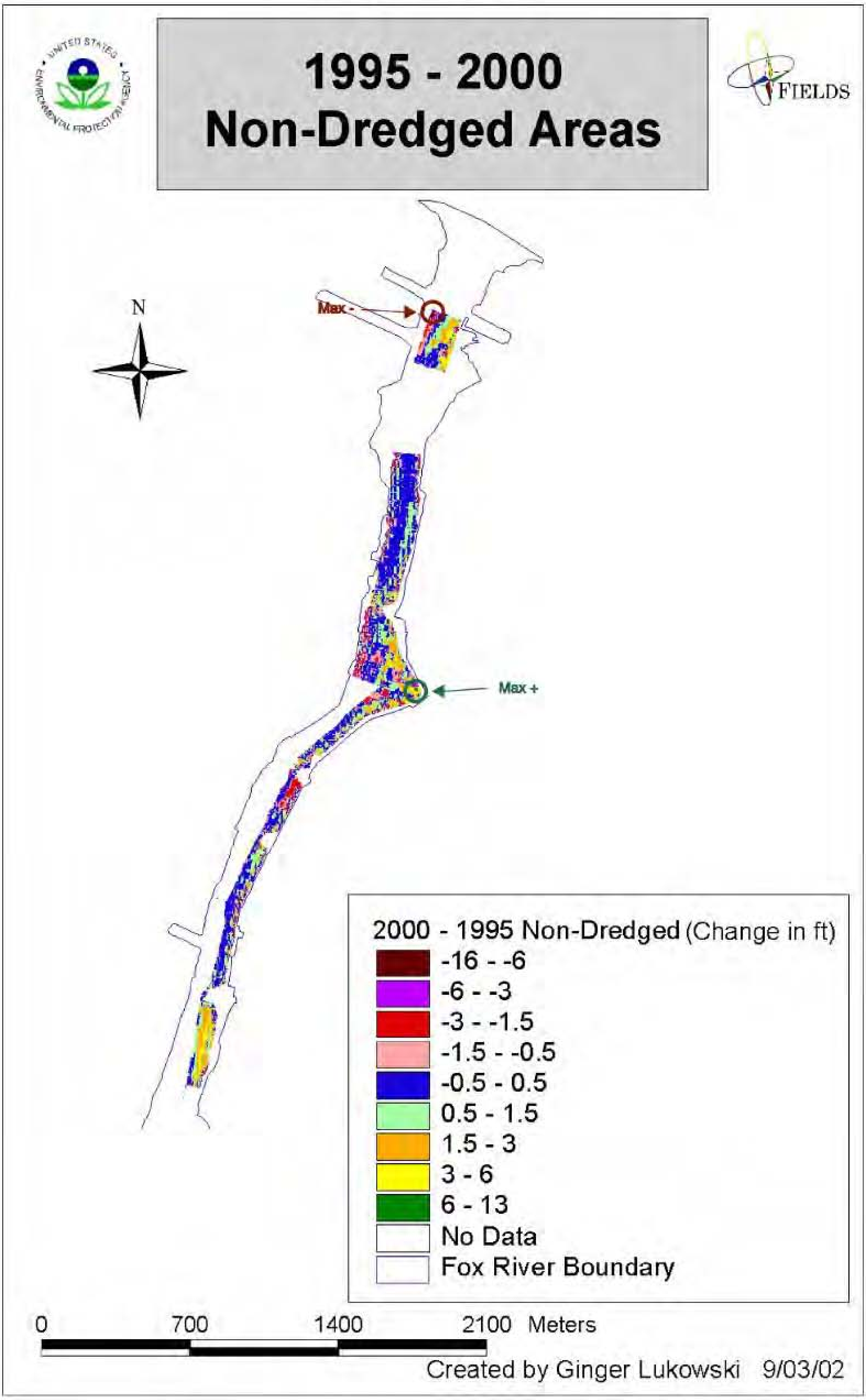
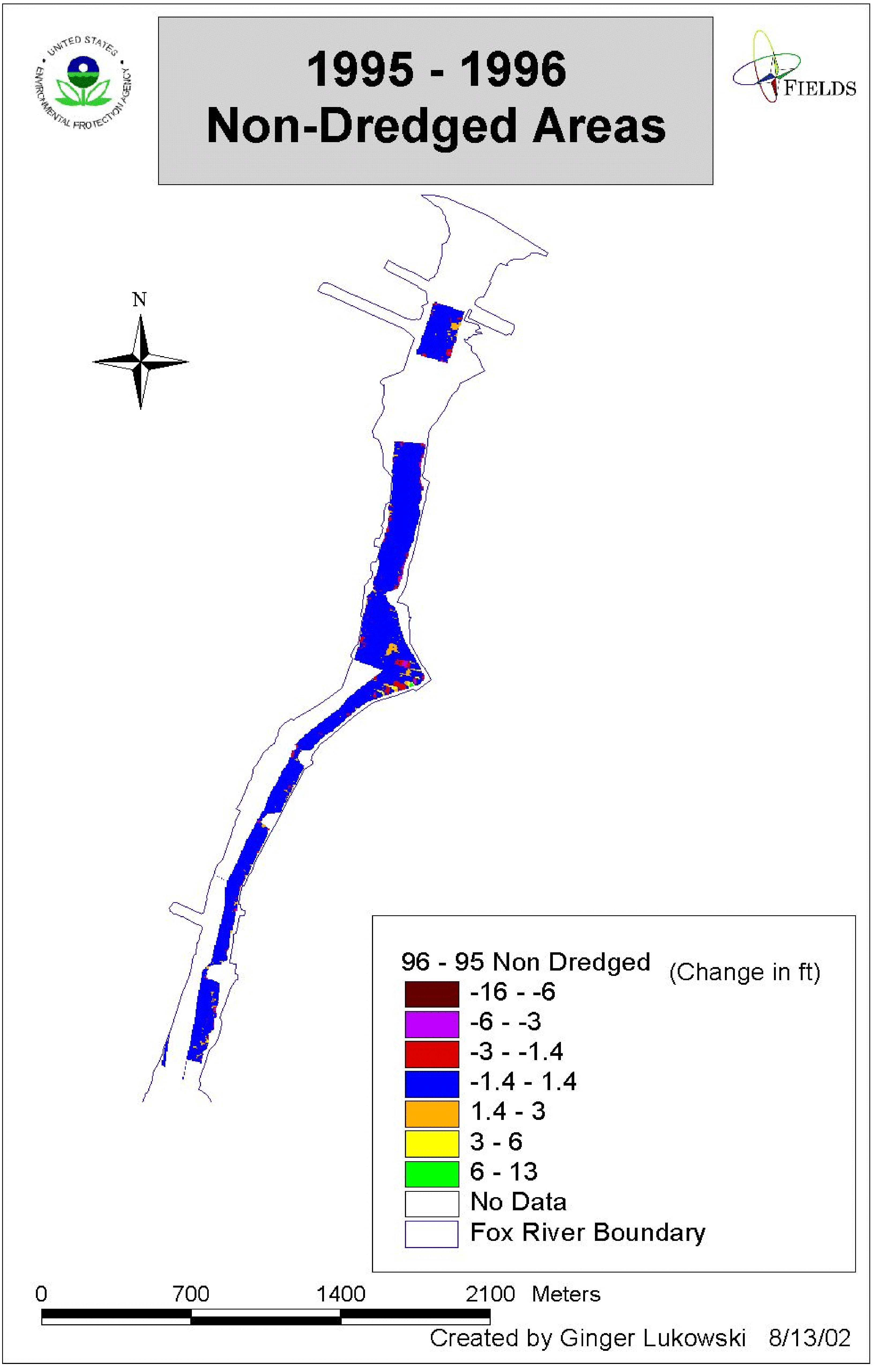

1995 - 2000
Non-Dredged Areas
FIELDS
N
Max -
Max +
2000 - 1995 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.5
-1.5 - -0.5
-0.5 - 0.5
0.5 - 1.5
1.5 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/03/02

**Figure 18a**



1995 - 1996
Non-Dredged Areas
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
N
96 - 95 Non Dredged
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100
Meters
Created by Ginger Lukowski 8/13/02

**Figure 18b**

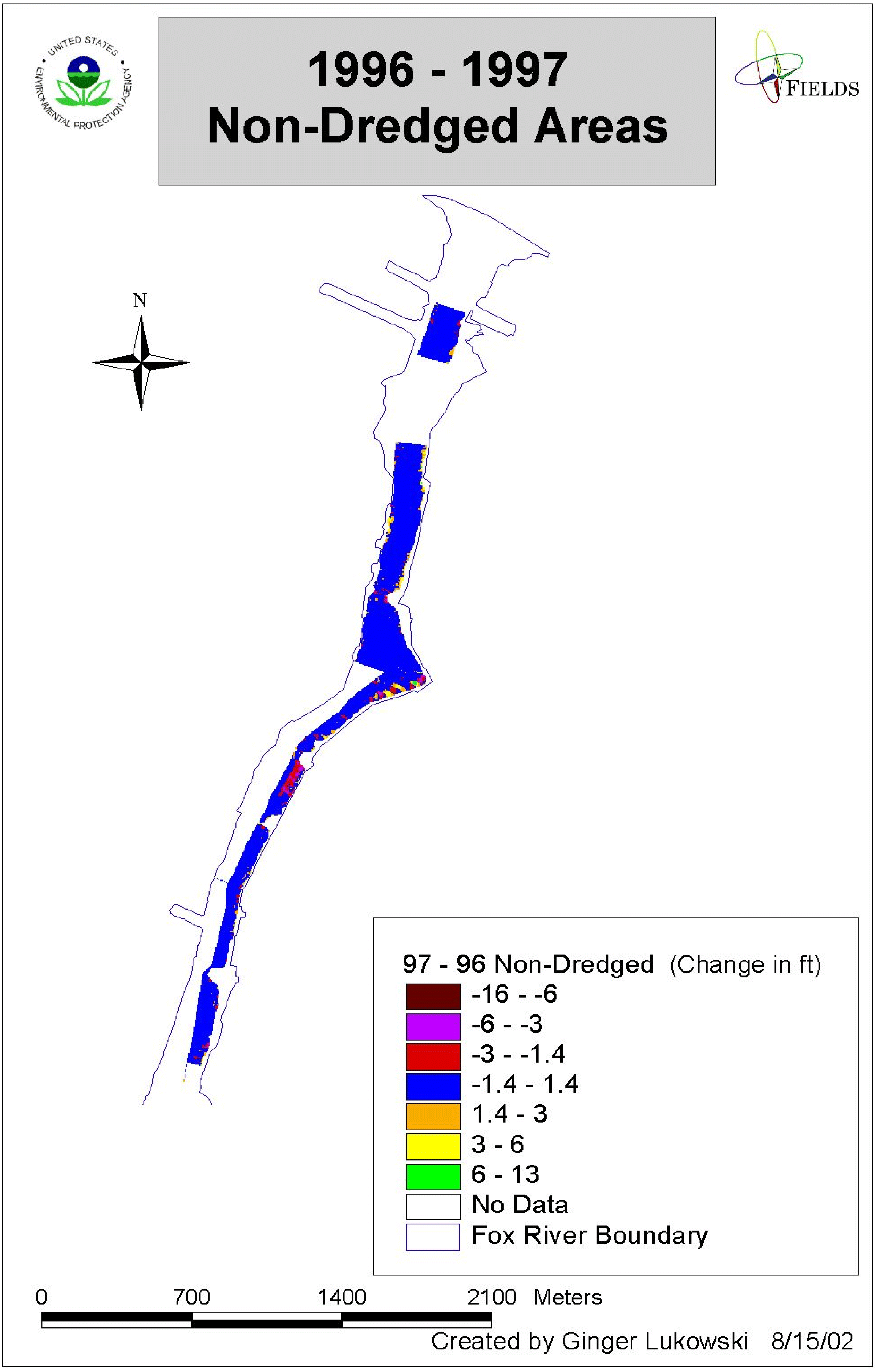

1996 - 1997
Non-Dredged Areas
FIELDS
N
97 - 96 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 8/15/02

**Figure 18c**

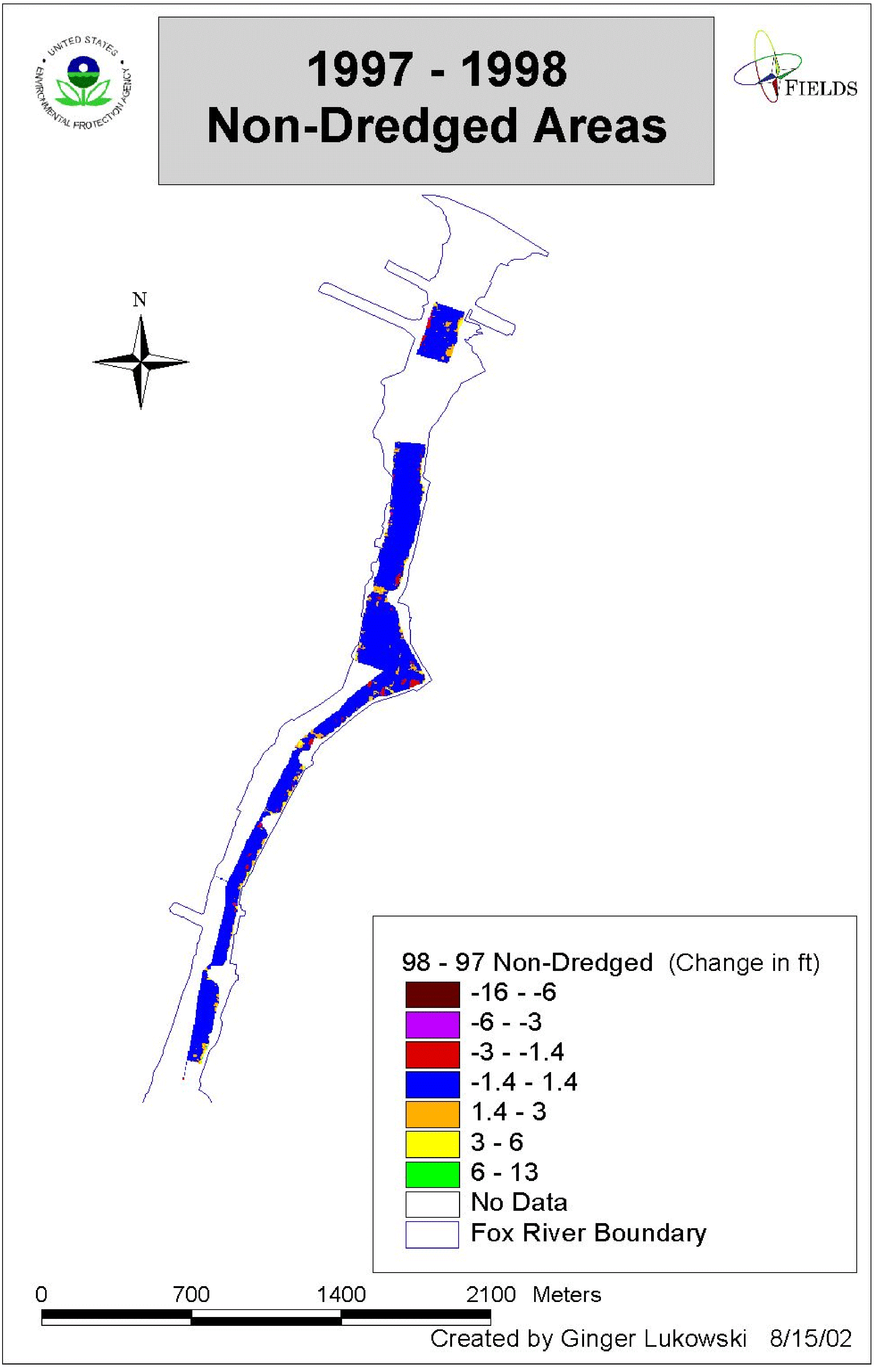
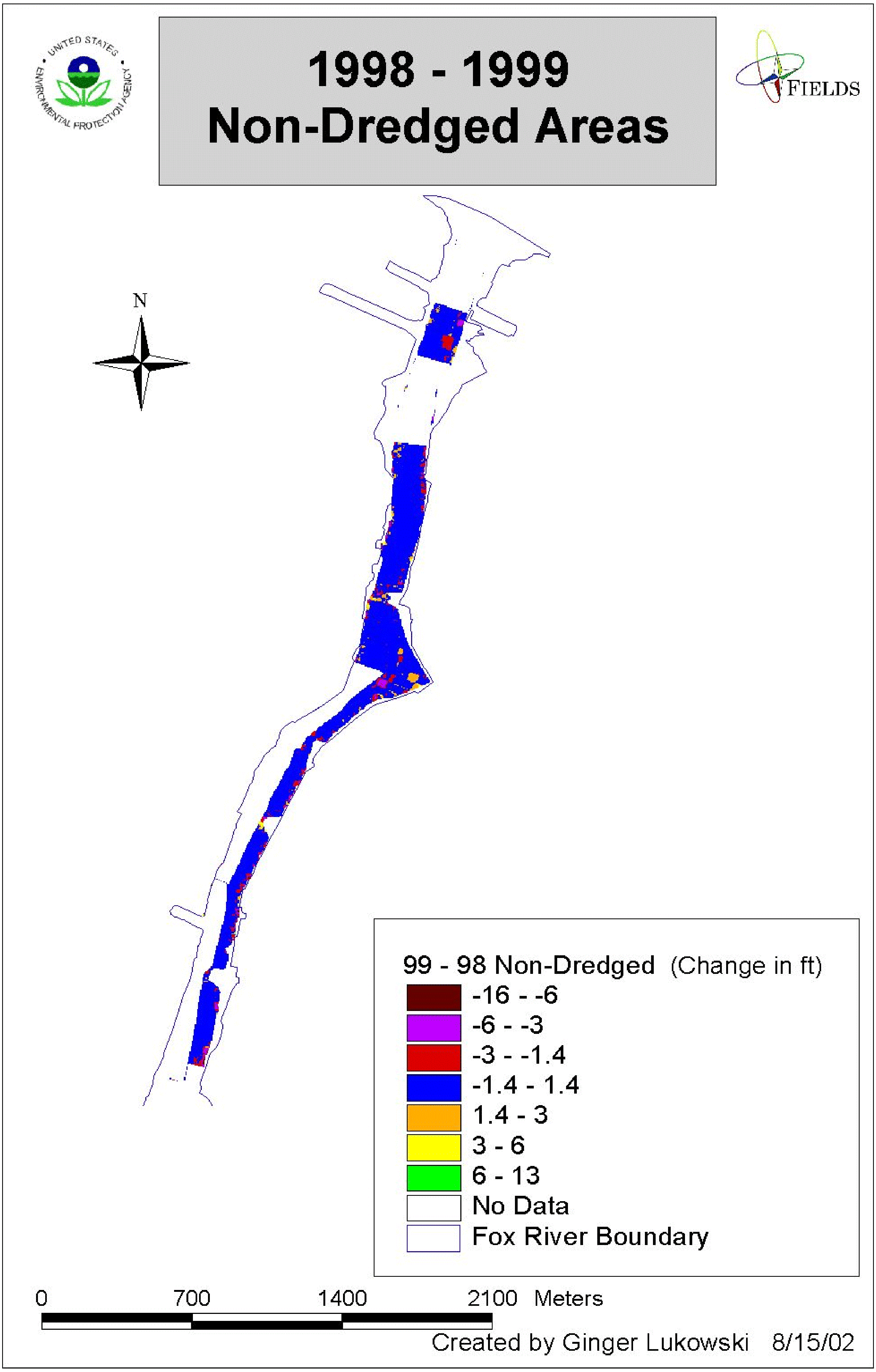

1997 - 1998
Non-Dredged Areas
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIELDS
N
98 - 97 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 8/15/02

**Figure 18d**



1998 - 1999
Non-Dredged Areas
FIELDS
N
99 - 98 Non-Dredged (Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 8/15/02

**Figure 18e**

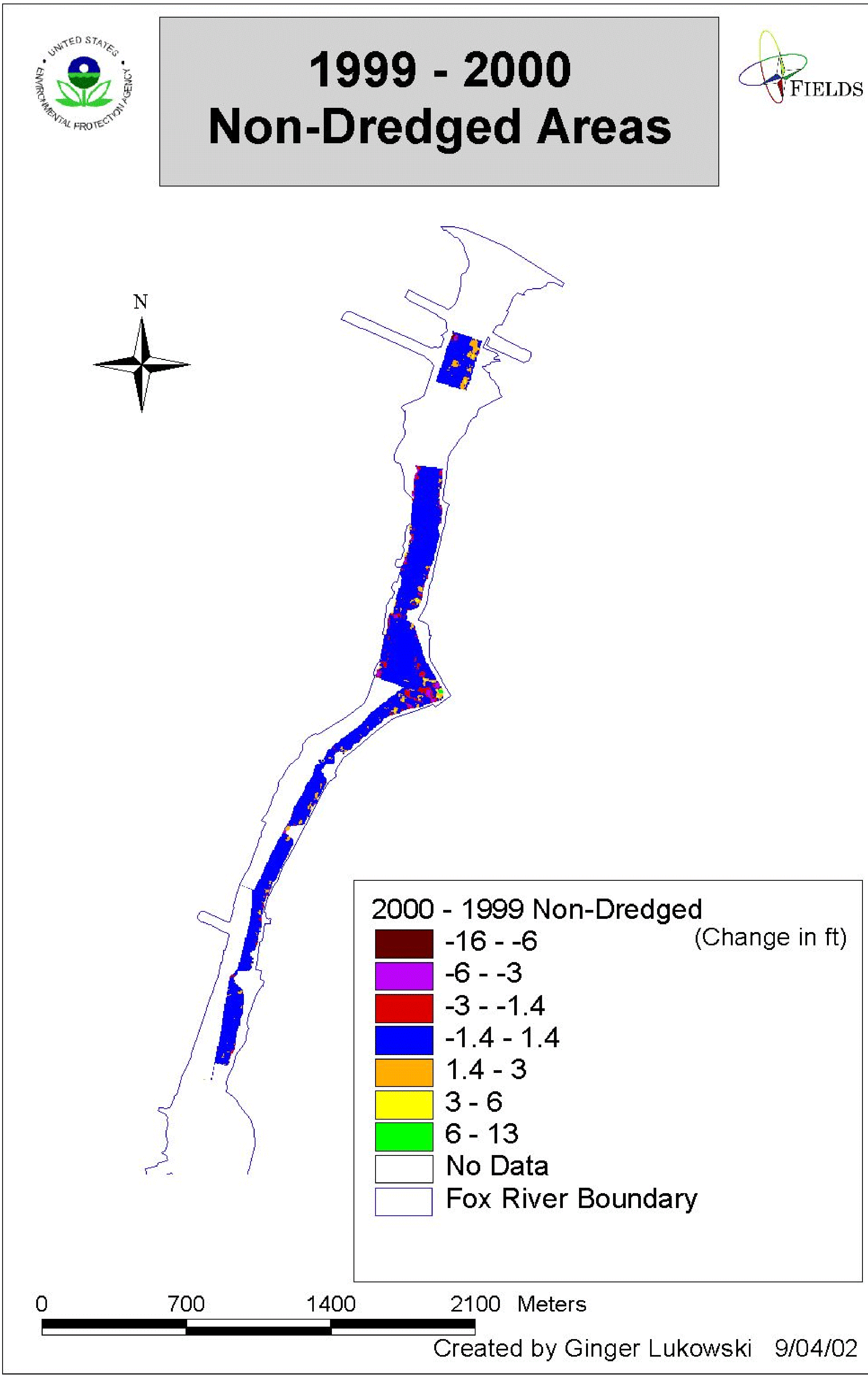
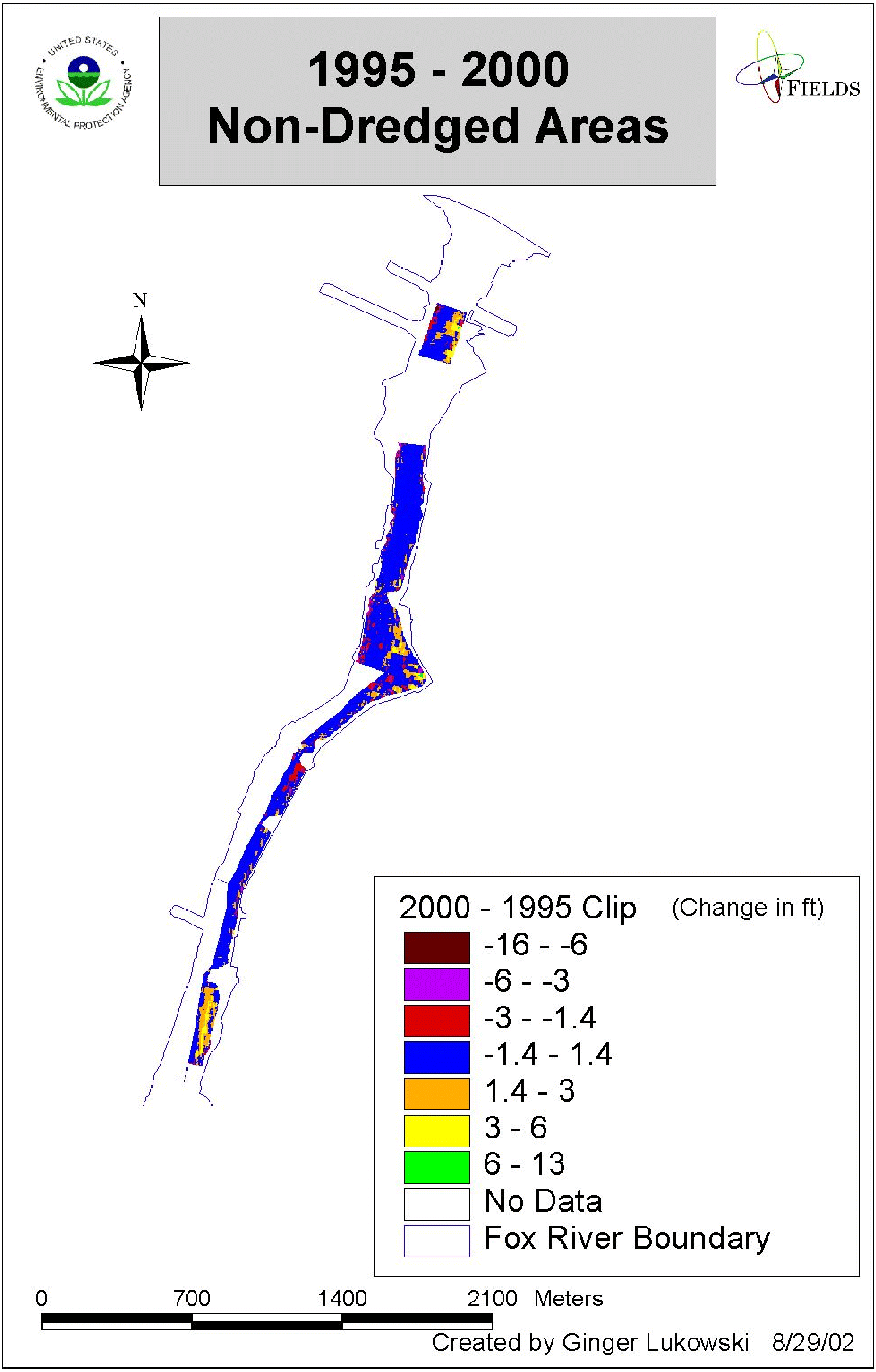

1999 - 2000
Non-Dredged Areas
FIELDS
N
2000 - 1999 Non-Dredged
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100 Meters
Created by Ginger Lukowski 9/04/02

**Figure 18f**



1995 - 2000
Non-Dredged Areas
FIELDS
N
2000 - 1995 Clip
(Change in ft)
-16 - -6
-6 - -3
-3 - -1.4
-1.4 - 1.4
1.4 - 3
3 - 6
6 - 13
No Data
Fox River Boundary
0
700
1400
2100
Meters
Created by Ginger Lukowski 8/29/02

# White Paper No. 4 –

# Dams in Wisconsin and on the Lower Fox River

***Response to Comments by The Fox River Group***

## Comments of the Fox River Group on the
## Wisconsin Department of Natural Resources'
## Draft Remedial Investigation, Draft Feasibility Study
## Draft Baseline Human Health and Ecological Risk Assessment
## and Proposed Plan

January 2002

***This Document has been Prepared by***

Wisconsin Department of Natural Resources

**December 2002**

# White Paper No. 4 –
# Dams in Wisconsin and on the Lower Fox River

## Abstract

In October 2001, the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA) released the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) for remediation on the Lower Fox River and Green Bay and other supporting documents for public input. Numerous comments were received from the public including comments concerning the dams that are located on the Lower Fox River. To assist in responding to these comments, the WDNR prepared the following review of the River dams.

This evaluation found that the dams on the Lower Fox River are subject to state and federal regulation, that most of the dams are regulated for energy production and are not primarily flood control structures, that there are no plans to remove any of the dams, and there is concern regarding the release of upstream contaminated sediment in the event of a dam removal or failure. Inspection and dam stability information on the dams owned and operated by the United States Army Corp of Engineers (USACE) reveals that the dams are regularly inspected, have post-inspection maintenance conducted, and have no significant stability concerns.

## Background

The first dam built in Wisconsin was built in 1809 to provide power for a sawmill on the Fox River at De Pere. Black River saw its first sawmill in 1819, and in 1831 one was built on the Wisconsin River. These early dams aided people in providing flowages for transporting goods, and for powering lumber and grain mills. The first state regulation of dams began with the Milldam Act, a part of the Wisconsin Territorial Laws of 1840, No. 48. The purpose of this act was to encourage the construction of mill-powering dams by permitting the flooding of the land of others without acquiring easements for millponds. These early dams provided for and encouraged settlement in Wisconsin.

In 1841, dams on navigable streams were required to obtain legislative permission, as a part of the Wisconsin Territorial Laws of 1841, No. 9. This helped encourage economic development, as well as protect the public interest in waterways. The Milldam Act was repealed in 1849 (Chapter 157), as the constitutionality of preventing compensation by flooded landowners was challenged at the Wisconsin Supreme Court. The impoundments created by dams were viewed as a public resource, and therefore it was argued that private land, such as the land being flooded by these dams, could not be taken from its landowners for public use without compensation being given to the landowner. In 1857, the Milldam Act was revived under Chapter 62, Laws of 1857, but was repealed and recreated in 1858. In a court case in 1860, it was stated by the court that the Milldam Act would be overruled if it were not for precedent and economic benefits, and therefore the Milldam Act was constitutional.

In 1863, it was declared that navigable waterways are public highways. In the following years, the "sawlog" test was developed to determine navigability. In 1909, the legislature decided they no longer had the time or expertise to issue permits for dams and that responsibility was given to state agencies.

For much of the early 1900s, the Railroad Commission and then the Public Service Commission (PSC) had jurisdiction over dams. Laws changed over the years to address issues such as the rights of upstream and downstream landowners, the debate over navigable and non-navigable rivers, and public safety rights. In 1967, the WDNR was created, and jurisdiction over dams was handed over from the PSC to the WDNR. In the early 1980s, the WDNR developed standards for design, construction, and reconstruction of large dams, and enacted Warning Sign and Portages for Dams rules for public safety. In 1991, procedures for implementation of a dam maintenance, repair, modification, or abandonment grant program were put into place.

The WDNR currently deals with permitting for new dam construction, repairs, reconstruction, ownership transfers, and abandonment. Many dams in the state have been in place since the late 1800s, and a great deal of time must be invested in inspecting aging dams and making sure they comply with public safety requirements and environmental regulations.

## WISCONSIN DAMS

There are approximately 3,700 dams inventoried in the State of Wisconsin. An additional 700 dams have been built and washed out or removed since the late $19^{th}$ century. The federal government has jurisdiction over large dams that produce hydroelectricity – approximately 5 percent of the dams in Wisconsin. The WDNR regulates most of the rest of the dams. Approximately 50 percent of the dams in Wisconsin are owned by private individuals, 19 percent by the State of Wisconsin, 16 percent by municipalities such as townships or county governments, and 15 percent by other ownership types.

A dam with a structural height of over 6 feet and impounding 50 acre-feet or more, or having a structural height of 25 feet or more and impounding more than 15 acre-feet is classified as a large dam. There are approximately 1,200 large dams in Wisconsin. Dams are classified as *High Hazard* when their failure would put lives at risk. The "hazard" rating is not based on the physical attributes, quality, or strength of the dam itself, but rather the possibility of loss of life and property should the dam fail.

The Public Trust Doctrine emanates from Article IX, Section 1 of the Wisconsin Constitution. It states that all rivers, lakes, and navigable waterways are under the jurisdiction of the State of Wisconsin. Any structure which is built on a waterway impacts the public rights to that waterway, and needs to be monitored by the State of Wisconsin to assure safety, water quality, public access, and monitor its impact on Wisconsin wildlife.

### Dam Safety Program

Chapter 31, created in 1917 under the Water Power Law, was developed to ensure that dams are safely built, operated, and maintained. NR 333 provides design and construction standards for large dams and NR 335 covers the administration of the Municipal Dam Repair and Removal Grant Program. WDNR is responsible for administration of these regulations. Chapter 31 covers:

- Dam permitting;
- Dam construction;
- Dam safety, operation, and maintenance;
- Alteration or repair of dams;
- Dam transfer and dam removal; and
- Water level and flow control.

In regards to dam safety inspections, Chapter 31.19 requires the department to inspect all of the large dams on navigable waterways once every 10 years. However, WDNR does not typically inspect dams that are regulated by a federal agency.

### Dam Removal

Dams have been built and removed in Wisconsin for almost 200 years. In the early years, when a dam no longer provided a functional or economic purpose it was removed from the stream. Many of the dams in the state today have been in place for years. While many of these no longer provide their original function, they have become a part of the communities' identity. This can make decisions about whether to perform costly upgrades to dams or remove them very difficult.

The WDNR is required to review and approve all applications for dam abandonment and removal. Consideration of abandonment/removal has usually come about because of a failure incident or as the result of a WDNR inspection that found significant defects that requires major repairs to correct. Economic, social, and environmental factors all play a significant role in the decision to remove dams.

## HISTORY AND POLICY

In recent decades, Wisconsin has seen a large number of its historic dams aging and falling into disrepair. In most cases, WDNR has remained neutral in the decision-making process, only seeking to correct safety deficiencies at dams. As dam removals have been accomplished over the last 20 years, significant improvements have been noted in water quality, habitat, and biodiversity at many of these sites. In light of this, in recent years, WDNR has advocated for the removal of certain dams for the purpose of stream and habitat restoration.

In all cases, WDNR's activities related to dam removal included assuring the project meets the statutory requirements of Chapter 31 and is completed in a manner that protects the public rights in navigable waters and public safety. In cases where we advocate dam removal, we have participated in public information meetings to explain the benefits of dam removal to the surrounding ecosystem and assisting with funding to accomplish removal and restoration activities. In the future, these types of efforts will probably continue on a selective basis, driven by watershed plans that identify dams that are most detrimental to the ecosystem. These efforts cannot be accomplished without a willing owner or if there is a responsible party that is willing and able to take over ownership of the dam and properly operate and maintain the structure.

Almost 100 dams have been removed from Wisconsin streams since 1967. The dam inventory lists over 900 dams that have been built and removed since the 1800s. Removed dams have ranged in size from small dams on trout streams such as the Cartwright dam on Shell Creek, medium size dams such as the Ontario dam on the Kickapoo River, and fairly large dams on warm-water streams such as the North Avenue dam on the Milwaukee River.

## REASONS FOR REMOVAL

The three major reasons for dam removals in Wisconsin are:

- Removal of an unsafe structure under Chapter 31.19 of our state statutes. Under Chapter 31.19 the WDNR is required to inspect "large" dams at least once every 10 years to ensure their safety.
- Chapter 31.187 charges the WDNR with removing "abandoned" dams when either no owner is found or the owner or owners are not able to fund repairs.
- In a few cases, WDNR has removed or proposed to remove dams that have a significant environmental impact. Many of those are on WDNR properties.

## DECISION-MAKING PROCESS

The normal process in which a removal might be considered would involve a dam that has been identified as deficient through a failure or an inspection. The dam owner would then be contacted if an owner can be identified, and notified of the problems and given a timeline to correct all deficiencies. An official order may be given, ordering the dam owner to either perform the needed repairs or remove the structure – repair or removal is their choice. If the dam owner is considering removal, or if it is not economically feasible for the dam owner to repair the dam (dam removal generally costs one-third of estimated reconstruction costs), the owner submits an application to abandon the permit of the dam and a plan for removal of the structure. At this point, a public information meeting is often held, in which the WDNR explains the situation and gains public input. If the owner chooses to pursue dam removal, an Environmental Assessment may then be prepared, followed by public notice, which provides the opportunity for a contested case hearing. Once these steps are complete, a permit to abandon the dam will be issued with conditions for removal.

## ENVIRONMENTAL BENEFITS

With regard to resource management, the most significant benefits of dam removal include:

- Reconnection of important seasonal fish habitat;
- Normalized temperature regimes;
- Improved water clarity (in most cases);
- Improved dissolved oxygen concentrations;
- Normalized sediment and energy transport; and
- Improved biological diversity.

In general, carp prefer the warm waters of an impoundment, yet when a dam is removed the cool water species such as trout and bass, generally preferred by anglers, can move back into the river and repopulate.

### Dams on the Lower Fox River

Table 1, Lower Fox River Dam, is a summary of the location and pertinent information on the dams for the Lower Fox River from Lake Winnebago to Green Bay. In that stretch of the River, there are 13 existing dams and one dam that was abandoned. Of the existing dams, all are classified as large. Nine of these dams have a high hazard potential while four have a significant hazard rating. A majority of these dams (11) are licensed by the Federal Energy Regulatory Commission, suggesting that the dams' primary purpose is energy related, not flood control. While all of the dams have some potential for the release of contaminated sediments from upstream sediment deposits, the database maintained by the WDNR's Dam Safety Program specifically lists the releases of contaminated sediments as a concern relative to dam failure scenarios or immediate need for drawdowns for six of these dams.

Joint dam ownership is quite common for the dams along the Fox River. Eight dams have at least partial ownership by the USACE. Sections of some of these dams are also under private ownership. Negotiations are continuing between the State of Wisconsin and the USACE relative to transfer to the state the "transportation locks" portion from the USACE. The USACE (and co-owners) will retain the ownership of the dams. At this time, the WDNR is not aware of any plans to remove any of these dams. Of the Lower Fox River dams, WDNR Dam Safety staff has indicated that the De Pere dam may be in need of repairs; however, they do not believe that there is a concern of a catastrophic failure.

### Inspection and Stability of Dams Owned or Partially Owned by the USACE

Eight of the dams on the Lower Fox River from Lake Winnebago to the mouth of the Fox River at Green Bay are either fully or partially owned by the USACE. The WDNR reviewed past periodic inspection and the conclusions of stability analysis for each of these dams. The results of this review are found in Table 2, Lower Fox River – U.S. Army Corps of Engineers – Dam Stability and Inspection Information, of this summary. In general, the stability analysis indicated that the spillway and sluiceway sections of the dams have adequate compression to resist overturning, and they have adequate bearing capacity to support the maximum base pressure. While inspections did reveal various potential problems, such as the need for concrete repairs, the overall conclusion of the reports were that dams were found to be in good condition overall and no structural deficiencies were found which would affect the operation of the dam. Many of the inspection reports recommended development of a plan to prioritize concrete the repairs for the dams on the Fox River over a subsequent 5-year period. The USACE has stated that maintenance recommended by the routine inspection is conducted.

## REFERENCES

This information is from WDNR's Dam Safety, Floodplain, and Shoreland Program's website concerning dam safety. In addition, the website provide more information such as frequently asked questions about the dams in Wisconsin. This website can be viewed at http://www.dnr.state.wi.us/org/water/wm/dsfm/dams/index.html.

The sources of information for Table 2 included copies of the inspection reports and the conclusions of the stability analysis including:


- *Menasha Dam, Dam Stability Analysis, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District, NCD. December 1987.
- *Menasha Dam, Fourth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. August 23, 1994.
- *Appleton Lower Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. January 1997.
- *Appleton Upper Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. September 1985.
- *Appleton Dams, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. June 7, 1995.
- *Cedars Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. January 1997.
- *Cedars Dam, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. June 6, 1995.
- *Rapide Croche Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. May 1997.
- *Rapide Croche Dam, Fourth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. August 24, 1994.

- *Little Chute Dam, Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. April 1997.
- *Little Chute Dam, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. May 22, 1996.
- *Little Kaukauna Dam, Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. November 1996.
- *Little Kaukauna Dam, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. May 26, 1996.
- *Kaukauna Dam, Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. May 1997.
- *Kaukauna Dam, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. May 21, 1996.
- *De Pere Dam, Stability Analysis, Fox River, Wisconsin, Final Report*. United States Army Corps of Engineers, Detroit District. April 1997.
- *De Pere Dam, Fifth Periodic Inspection, Fox River, Wisconsin*. United States Army Corps of Engineers, Detroit District. June 8, 1995.

WDNR and EPA, 2001. *Proposed Remedial Action Plan, Lower Fox River and Green Bay*. Wisconsin Department of Natural Resources, Madison, Wisconsin and Green Bay, Wisconsin and United States Environmental Protection Agency, Region 5, Chicago, Illinois. October.

## TABLE 1 LOWER FOX RIVER DAM

| Dam Seq. No. | Dam Official Name/ Popular Name | Field File No. | FERC License No. | Dam Size[1] | Owner Name | Hydraulic Height (feet) | Structure Height (feet) | Impound. Surface Area (acres) | Max. Impound. Storage (acre/ft) | Hazard Potential[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| 601 | Neenah | 70.03 | | Large | Neenah & Menasha Power Co. | 9.0 | 15.0 | 137,708.0 | 1,100,000.0 | High |
| 757 | Menasha | 70.02 | 2352 | Large | USACE | 9.0 | 16.0 | 280.0 | 1,300,000.0 | High |
| 789 | Upper Appleton/ Vulcan | 44.03 | 2895 | Large | USACE & others | 14.0 | 22.0 | 1,306.0 | 14,300.0 | High |
| 166 | Middle Appleton | 44.02 | 2807 | Large | Fox Valley Corp. | 10.0 | 18.0 | 35.0 | 200.0 | High |
| 788 | Lower Appleton | 44.01 | | Large | USACE | 9.0 | 15.0 | 50.0 | 520.0 | High |
| 790 | Kimberly/Cedars | 44.07 | 10674 | Large | USACE | 12.0 | 16.0 | 270.0 | 2,300.0 | High |
| 722 | Little Chute | 44.11 | 2588 | Large | USACE & others | 14.0 | 18.0 | 80.0 | 660.0 | Significant |
| 720 | Combined Locks | 44.04 | 2715 | Large | City of Kaukauna | 20.0 | 30.0 | 130.0 | 1,040.0 | Significant |
| 81 | Kaukauna/Upper Kaukauna | 44.06 | 1510 | Large | DAEN NCC, City of Kaukauna | 25.0 | 27.0 | 120.0 | 800.0 | High |
| 4222 | Middle Kaukauna | 44.09 | | | Outagamie Paper Co. | 12.0 | | | | Abandoned |
| 721 | Lower Kaukauna/City Plant & Badger | 44.08 | 2677 | Large | City of Kaukauna | 9.0 | 16.0 | 40.0 | 200.0 | High |
| 791 | Rapide Croche | 44.10 | 2677 | Large | USACE | 10.0 | 14.0 | 530.0 | 7,000.0 | High |
| 805 | Little Kaukauna/Little Rapids | 5.02 | 11596 | Large | USACE & others | 7.0 | 16.0 | 344.0 | 4,240.0 | |
| 804 | De Pere | 5.01 | 4914 | Large | USACE & others | 8.0 | 17.0 | 994.0 | 8,240.0 | |

**Notes:**

[1] Dam Size. A dam with a structural height of over 6 feet and impounding 50 acre-feet or more, or having a structural height of 25 feet or more and impounding more than 15 acre-feet is classified as a large dam.

[2] Hazard. Dams are classified as High Hazard when their failure would put lives at risk. The “hazard” rating is not based on the physical attributes, quality, or strength of the dam itself, but rather the possibility of loss of life and property should the dam fail.

## TABLE 2 LOWER FOX RIVER – U.S. ARMY CORPS OF ENGINEERS – DAM STABILITY AND INSPECTION INFORMATION

| Name | Stability | | Inspection | |
|---|---|---|---|---|
| | Date | Comments from analysis | Date | Comments from analysis |
| Menasha Dam | December 1987 | Spillway meets current structural stability requirements.<br>Sluiceway areas of scour need immediate repair; areas of little or no scour meet stability criteria. | August 1994 | Menasha dam is in good condition overall and no structural deficiencies were found which would affect the operation of the dam.<br>In 1989, 1,200 tons of armor stone were placed to fill scour holes. |
| Appleton Lower Dam | January 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | June 1995 | Appleton lower dam was found to be in satisfactory condition, but can be expected to degrade with time. No significant structural deficiencies were found that would affect safety or operation of the dam. |
| Appleton Upper Dam | September 1985 | The analysis indicated that the Appleton upper dam monoliths meet current stability criteria, including sliding, overturning and bearing capacity requirements. | June 1995 | Appleton upper dam was found to be in satisfactory condition, but can be expected to degrade with time. No significant structural deficiencies were found that would affect safety or operation of the dam. |
| Cedars Dam | January 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | June 1995 | The Cedars dam was found to be in satisfactory condition. No significant structural deficiencies were found that would affect safety or operation of the dam. |
| Little Chute | April 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | May 1996 | The Little Chute dam was found to be in acceptable condition. The areas of main concern are along the earthen structures that connect the concrete dam to high ground. The project can be expected to perform safely if the recommendations made in the inspection report are implemented. |
| Rapide Croche | May 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | August 1994 | The Rapide Croche dam was found to be in acceptable condition. The concrete of the piers is in various stages of deterioration, and can be expected to continue to degrade. The project can be expected to perform safely, but with maintenance and importance of detailed inspections will increase with age. |

## TABLE 2 LOWER FOX RIVER – U.S. ARMY CORPS OF ENGINEERS – DAM STABILITY AND INSPECTION INFORMATION

| Name | Stability | | Inspection | |
|---|---|---|---|---|
| | Date | Comments from analysis | Date | Comments from analysis |
| Little Kaukauna | November 1996 | The lateral defection of the pile cap (spillway or sluiceway section) exceeds 0.5 inch in all cases except the flood discharge condition for both the spillway and sluiceway sections. Ice loads will cause large lateral deflections, often exceeding the generally allowable value of 0.5 inch for this type of structure. The axial compressive forces in the piles are more than the allowable values for almost all the piles for usual and unusual conditions, and for most of the piles for these conditions. No piles were found in tension. | May 1996 | The Little Kaukauna dam was found to be in satisfactory condition. No significant structural deficiencies were found which would affect the safety or operation of the dam. The project can be expected to continue to perform safely, provided normal maintenance and monitoring operations are followed and the recommendations of the inspection report are carried out. |
| Kaukauna | May 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | May 1996 | The Kaukauna dam was found to be in satisfactory condition. No significant structural deficiencies were found which would affect the safety or operation of the dam. The project can be expected to continue to perform safely, but the maintenance and the importance of detailed inspections will increase with time. |
| De Pere | April 1997 | Spillway and sluiceway sections have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. | June 1995 | The De Pere dam was found to be in satisfactory condition. No significant structural deficiencies were found which would affect the safety or operation of the dam. The project can be expected to continue to perform safely, but the maintenance and the importance of detailed inspections will increase with time. |

**Note:**

[1] Sources of Information – Copies of the Inspection Reports and the conclusions of the Stability Analysis can be found at the WDNR RR Program files for the Fox River at the Gef II office building in Madison, Wisconsin.

# WHITE PAPER NO. 5A – RESPONSES TO THE API PANEL REPORT

***Response to a Document by The Johnson Company***

## ECOSYSTEM-BASED REHABILITATION PLAN –
## AN INTEGRATED PLAN FOR HABITAT ENHANCEMENT AND
## EXPEDITED EXPOSURE REDUCTION IN THE
## LOWER FOX RIVER AND GREEN BAY

January 2002

***This Document has been Prepared by***
Wisconsin Department of Natural Resources

**December 2002**

# WHITE PAPER NO. 5A – RESPONSES TO THE API PANEL REPORT

## ABSTRACT

Appleton Papers, Inc. (API) provided funding to assemble a panel of university professors and scientists to evaluate the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001). The Appleton Paper, Inc. Panel (referred to as “the API Panel”) completed a report entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (referred to herein as the “Panel Report”) dated January 17, 2002 (The Johnson Company, 2002) that was submitted as part of the comments during the public response period. The Panel Report contended that the Agencies’ proposed contaminated sediment removal plan would be limited by water quality discharge issues, and that risk reduction could be better achieved by capping areas of contaminated sediments within the Lower Fox River. They further purported that the capping would also result in habitat enhancement.

This White Paper is one in a series of papers that focuses on evaluating the claims of the Panel Report. Specifically, this paper evaluates the API Panel’s basis for estimating risk reduction as the sediment-weighted average concentration (SWAC). This White Paper evaluates the Panel Report’s polychlorinated biphenyl (PCB) SWAC computations with those presented in the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a) and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b).

The following findings are presented in this White Paper:

- The Panel Report does not follow National Research Council guidance in that it does not develop site-specific risk reduction numbers.

- The Panel Report does not propose risk reduction equivalent to the Proposed Plan. The SWAC proposed by the API Panel is two to three times that selected for the Proposed Plan and is based upon engineering implementability and not risk reduction.

- The SWAC reported in the Panel Report is inaccurate; the recalculated SWAC is up to four times greater than that selected for the Proposed Plan.

- The Remedial Action Level (RAL) needed to achieve the recalculated Panel Report SWAC for all reaches is 5 ppm.

- Directly comparing the costs and time to achieve the SWAC between the Proposed Plan and the Panel Report is not a direct comparison. In order to make those comparisons, the API Panel’s proposed remedy would need to be compared to the 5 ppm RAL from the FS.

## PURPOSE

The purpose of this white paper is to compare the SWAC developed and presented within the Wisconsin Department of Natural Resource's (WDNR's) Proposed Plan, with those proposed by the API Panel. The API Panel included their estimations as part of the Panel Report dated January 17, 2002 (The Johnson Company, 2002). In order to understand the API Panel's position, it was first necessary to compare the post-remedy SWAC in the Proposed Plan and the Panel Report to determine if there is a comparable level of risk reduction between them. This white paper provides that basis for comparison.

During the review of the Panel Report, it became apparent that the API Panel did not have the benefit of being able to accurately estimate the SWAC in a manner comparable to that done for the FS. For the FS, detailed PCB distribution maps were generated using all existing sediment data; interpolating the PCB concentration over the area of the Operable Unit (OU). These methods are described within the RI and FS, and detailed in Technical Memorandum 2e (WDNR, 1999). As part of the interpolation, a SWAC could be generated by summing the literally thousands of individual data points in the bed maps, and averaging those over the area of the OU. By contrast, the Panel Report digitized the RI maps, assumed a 50 percent concentration within an existing concentration isopleth,[1] and then averaged across the area of the OU. While the API Panel had access to Technical Memorandum 2e, the Fox River Database, and all bed maps produced, they chose not to follow the same methodology. Why they chose this alternate, imprecise method is never explained. The method the Panel Report used also assumes a normal distribution across the range, but this is not consistent with the actual data.

The relationship between sediment concentrations of PCBs and their direct link to risks were documented within the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c), and developed further into RALs in the FS. The BLRA and the FS followed the guidance put forth by the National Academy of Sciences (NAS) (NRC, 2001) in developing site-specific risk reduction goals. These goals, as articulated in Section 5 of the FS, are to reduce risks to human health and the environment. From a range of potential RALs, WDNR and the United States Environmental Protection Agency (EPA) selected 1 ppm, which would result in SWACs of 0.19, 0.27, and 0.16 ppm in OUs 1, 3, and 4, respectively. The API Panel proposed that a SWAC of 0.5 ppm be used as a design criterion. The proposed SWAC was not based on a site-specific assessment of risk, but rather on an engineering "implementation efficiency" estimation, and the API Panel developed their proposed capping areas and the Panel Report on that SWAC.

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1 In the Panel Report, these calculations are presented in Exhibits 1 and 2, with the average surficial PCB concentrations as 50 percent of the mapped range. For example, within OU 1, the area within the 5 to 10 parts per million (ppm) isopleth was assumed to be at 50 percent; i.e., was reported as 7.5 ppm. Concentrations greater than 50 ppm were assumed to be at 50 ppm, notwithstanding the fact that concentrations as high as 350 ppm were present.

## PROCEDURE

To compare the estimated SWACs developed by the API Panel, it was first necessary to overlay the API Panel-proposed capping areas onto the bed maps developed for the RI. Once those areas were delineated, then the resultant SWAC could be recalculated. Plots were created for OUs 1, 3, and 4, and the SWACs recalculated for each of the units. The recalculated SWAC was then compared to the number estimated and reported by the API Panel.

The capping areas proposed by the API Panel for OUs 1, 3, and 4 of the Lower Fox River are depicted on Figures 7, 8, and 9 in the Panel Report. To overlay the proposed capping areas on the interpolated PCB concentration maps, the capping areas were digitized and imported into ArcView GIS software. Upon overlaying the areas on the interpolated PCB concentration maps, it was observed that the digitized capping areas did not completely fit within the footprint of the individual OUs and required some adjustment. The Panel Report does not appear to specify the target PCB concentrations considered for capping (e.g., Deposit A, Sediment Management Units [SMUs]), but simply describes capping the "highest relative concentrations of PCBs." Since the criteria for capping was not clear, an adjustment was made to the location of the capping areas to the best extent possible to match the areas specified on Figures 7, 8, and 9 in the Proposed Plan. When the digitized capping areas were compared to the Panel Report's areas, they were approximately 6 percent larger for OUs 1 and 3, and approximately 2 percent lower for OU 4. For the purposes of this response, it was was determined that these relatively small differences would not significantly affect the SWAC comparisons.

It should be noted that the API Panel utilized for their calculations the bed maps from the RI. Newer data that has been recently reported for OU 1, and discussed in *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples*, was not included in the Panel Report. Thus, the comparison here is solely based on those maps.

Upon overlaying the API proposed capping areas on the interpolated PCB concentration map, the respective SWACs were recalculated. The script used to calculate the SWAC by WDNR in the RI/FS was modified to recalculate the Panel Report SWAC. The step-by-step procedure for calculating the API Panel-derived SWAC is provided in Table 1.

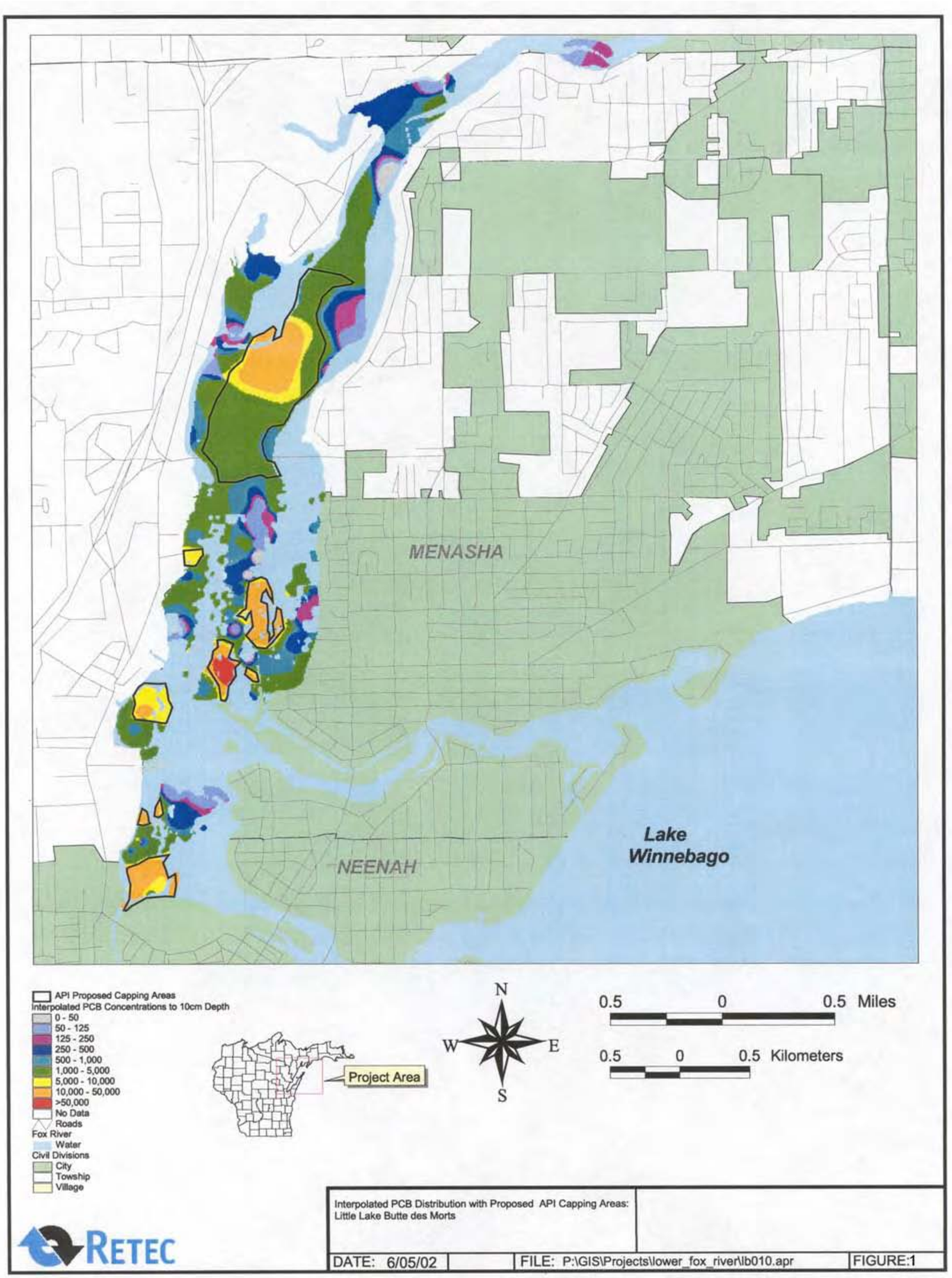
## TABLE 1 PROCEDURES USED TO RE-CALCULATE THE PANEL REPORT SWAC

| Step | Description | Action |
|---|---|---|
| 1 | **Open Mask Grids:** 0 for areas for with sediment and 1 for areas without sediment | Loads mask grid for Layer 1 (0 to 10 cm) |
| 2 | Open PCB-interpolated concentration grids | Loads PCB concentration grid for Layer 1 |
| 3 | Identify areas within Layer 1 for presence of sediment and interpolated value | Surface PCB grid is modified to 50 parts per billion (ppb) if the mask grid for that layer indicates no sediment present or if there is no interpolated value |
| 4 | Identify areas within Layer 1 for presence of cap | Surface PCB grid is modified to 50 ppb if cap coverage indicates the area is capped |
| 5 | Sum of surface PCB grid concentration over the entire reach divided by area of the reach | Generates summary table and SWAC grid for each River reach |

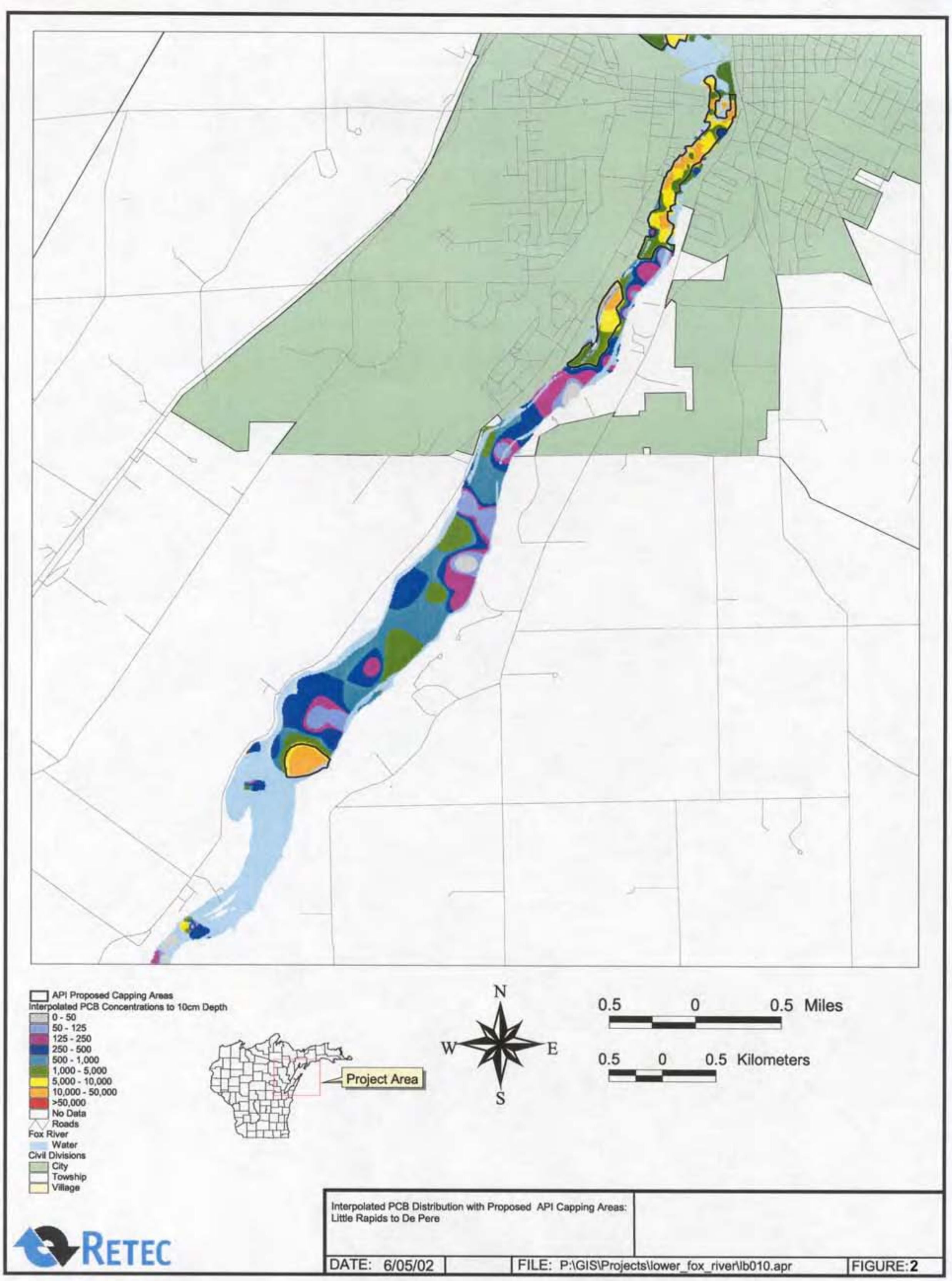
## RESULTS

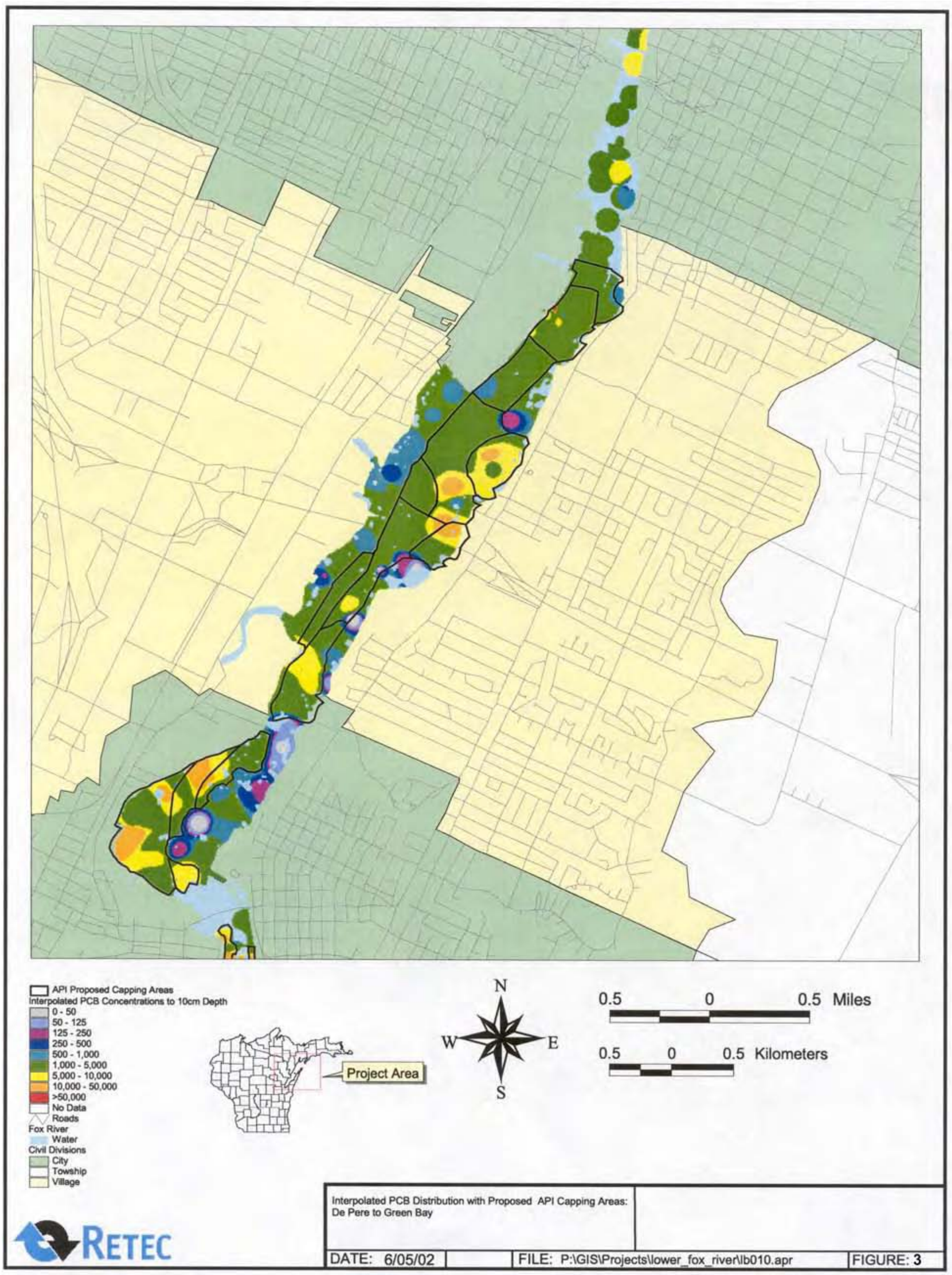
Figures 1 through 3 show the capping locations proposed by the API Panel for each of the three Operable Units. For OU 1, the capping areas correspond to those areas where PCB concentrations were greater than 5 ppm, with the exception that the API Panel did propose capping a larger section of Deposit E that included some portions where concentrations exceeded 1 ppm. Operable Unit 3 (Figure 2) follows a similar pattern, with portions of Deposit EE also included in the capping action. In OU 4, substantive portions of the entire reach are proposed for capping, including portions within the federal navigation channel. As noted above, the digitized areas corresponded within a few percentage points of the areas listed in the Panel Report.

Table 2 presents the comparison between the SWAC for each OU associated with the RAL of 1 ppm, the API Panel-reported SWAC, and the recalculated SWAC. The Panel Report has a stated goal of capping to achieve a SWAC of 0.5 ppm, and by their estimate the SWACs for OUs 1, 3, and 4 are 0.6, 0.53, and 0.54 ppm, respectively. Without recalculation, the API Panel SWACs are two to three times those selected by WDNR and EPA to be protective of human health and the environment. Table 2 also shows the results of recalculation of the SWAC in a manner consistent with the FS. As can be seen, the recalculated SWAC for OU 3 is fairly consistent with the API Panel estimate (0.56 ppm), but the SWAC for OUs 1 and 4 are higher (0.71 ppm), and are four times greater than the SWAC associated with the 1 ppm RAL identified in the Proposed Plan. For reference, Table 2 also shows that the RAL identified within the FS that would be most closely associated with the Panel Report SWAC of 0.7 ppm would be 5 ppm.



MENASHA
NEENAH
Lake Winnebago
API Proposed Capping Areas
Interpolated PCB Concentrations to 10cm Depth
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1,000
1,000 - 5,000
5,000 - 10,000
10,000 - 50,000
>50,000
No Data
Roads
Fox River
Water
Civil Divisions
City
Towship
Village
Project Area
N
W
E
S
0.5 0 0.5 Miles
0.5 0 0.5 Kilometers
RETEC
Interpolated PCB Distribution with Proposed API Capping Areas: Little Lake Butte des Morts
DATE: 6/05/02
FILE: P:\GIS\Projects\lower_fox_river\lb010.apr
FIGURE:1


API Proposed Capping Areas
Interpolated PCB Concentrations to 10cm Depth
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1,000
1,000 - 5,000
5,000 - 10,000
10,000 - 50,000
>50,000
No Data
Roads
Fox River
Water
Civil Divisions
City
Towship
Village
Project Area
N
W
E
S
0.5 0 0.5 Miles
0.5 0 0.5 Kilometers
RETEC
Interpolated PCB Distribution with Proposed API Capping Areas:
Little Rapids to De Pere
DATE: 6/05/02
FILE: P:\GIS\Projects\lower_fox_river\lb010.apr
FIGURE: 2


API Proposed Capping Areas
Interpolated PCB Concentrations to 10cm Depth
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1,000
1,000 - 5,000
5,000 - 10,000
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S
0.5 0 0.5 Miles
0.5 0 0.5 Kilometers
RETEC
Interpolated PCB Distribution with Proposed API Capping Areas:
De Pere to Green Bay
DATE: 6/05/02
FILE: P:\GIS\Projects\lower_fox_river\lb010.apr
FIGURE: 3

## TABLE 2 COMPARISON OF PROPOSED PLAN RAL AND SWACS WITH THOSE REPORTED AND RECALCULATED BY THE API PANEL FOR OPERABLE UNITS 1, 3, AND 4 IN THE LOWER FOX RIVER

| Operable Unit | Proposed Plan | | | Panel Report | | | |
|---|---|---|---|---|---|---|---|
| | RAL [1] (ppm) | SWAC [1] (ppm) | Total Area (acres) [2] | Reported SWAC (ppm) [3] | Recalculated SWAC (ppm) [4] | RAL Associated with API SWAC (ppm) [5] | Total Area (acres) [6] |
| 1 | 1 | 0.19 | 526 | 0.60 | 0.71 | 5 | 240 |
| 3 | 1 | 0.26 | 328 | 0.53 | 0.56 | 5 | 120 |
| 4 | 1 | 0.16 | 1,034 | 0.54 | 0.71 | 5 | 600 |

**Notes:**
[1] From Proposed Plan.
[2] Total Acres within the RAL remedial footprint.
[3] From API Panel Report
[4] Recalculated SWAC generated from the method in Table 1.
[5] RAL from Section 5 of the Draft FS.
[6] Total number of acres within the API Panel-defined remedial footprint (The Johnson Company, 2002).

## DISCUSSION

The following conclusions can be drawn from this analysis:

- The Panel Report does not follow National Research Council guidance in that it does not develop site-specific risk reduction numbers.

- The Panel Report does not propose risk reduction equivalent to the Proposed Plan. The SWAC proposed by the API Panel is two to three times that selected for the Proposed Plan and is based upon engineering implementability and not risk reduction.

- The SWAC reported in the Panel Report is inaccurate; the recalculated SWAC is up to four times greater than that selected for the Proposed Plan.

- The RAL needed to achieve the recalculated Panel Report SWAC for all reaches is 5 ppm.

- Directly comparing the costs and time to achieve the SWAC between the Proposed Plan and the Panel Report is not a direct comparison. In order to make those comparisons, the API Panel's proposed remedy would need to be compared to the 5 ppm RAL from the FS.

## REFERENCES

NRC, 2001. *A Risk Management Strategy for PCB-Contaminated Sediments*. National Research Council, National Academy of Sciences, Committee on Remediation of PCB-Contaminated Sediments. National Academy Press, Washington, D.C.

RETEC, 2002a. *Final Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin*. Prepared for Wisconsin Department of Natural Resources by The RETEC Group, Inc., St. Paul, Minnesota. December.

RETEC, 2002b. *Final Feasibility Study for the Lower Fox River and Green Bay, Wisconsin*. Prepared for Wisconsin Department of Natural Resources by The RETEC Group, Inc., Seattle, Washington. December.

RETEC, 2002c. *Final Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study*. Prepared for Wisconsin Department of Natural Resources by The RETEC Group, Inc., Seattle, Washington and Pittsburgh, Pennsylvania. December.

The Johnson Company, 2002. *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay*. Prepared for the Appleton Paper, Inc. Panel by The Johnson Company, Inc. January 17.

WDNR, 1999. *Model Evaluation Workgroup Technical Memorandum 2e: Estimation of Lower Fox River Sediment Bed Properties*. Wisconsin Department of Natural Resources. March 31.

WDNR, 2002. *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples*. Wisconsin Department of Natural Resources, Madison, Wisconsin. December.

WDNR and EPA, 2001. *Proposed Remedial Action Plan, Lower Fox River and Green Bay*. Wisconsin Department of Natural Resources, Madison, Wisconsin and Green Bay, Wisconsin and United States Environmental Protection Agency, Region 5, Chicago, Illinois. October.

# White Paper No. 5B – Evaluation of API Capping Costs Report

***Response to a Document by The Johnson Company***

## Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay

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***This Document has been Prepared by***

Wisconsin Department of Natural Resources

**December 2002**

# WHITE PAPER NO. 5B –
# EVALUATION OF API CAPPING COSTS REPORT

## ABSTRACT

This White Paper is the second in a series prepared in response to the Appleton Paper, Inc. Panel's (API Panel's) alternate proposed remedial activity plan entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (referred to herein as the "Panel Report") (The Johnson Company, 2002). As stated in *White Paper No. 5A – Responses to the API Panel Report*, the API Panel proposed remedial activities in the Panel Report which they contend would result in achievement of the risk reduction goals defined in the Remedial Action Objectives (RAOs) and would be more cost effective than the remedial activities in the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001). The Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA) disputed this conclusion, and this White Paper addresses various aspects of the Panel Report. Specifically, this paper evaluates the capping costs presented in the Panel Report.

The following findings are developed in this White Paper:

- The Panel Report does not accurately compare remedial costs. The Panel Report compares its alternatives developed at a less protective Remedial Action Level (RAL) (5 ppm) with the Proposed Plan RAL (1 ppm). The practical result of this decision is that the Panel Report develops costs for an area that is only one-half of that managed by the Proposed Plan.

- When compared at the same RAL (5 ppm), contaminated sediment removal alternatives in the *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002) are less expensive, or equivalent, in cost to the API Panel plan for all three Operable Units (OUs).

- The Proposed Plan removal alternative for OU 1 (dredge with off-site disposal), at an RAL of 1 ppm is equivalent in cost to the API Panel capping alternative.

- The Proposed Plan removal alternative for OUs 3 and 4 achieves permanent removal of polychlorinated biphenyls (PCBs) from the River at a lower (more protective) RAL, but are within 23 to 25 percent of the costs proposed by the Panel Report.

- The Panel Report costs, when projected onto the 1 ppm RAL footprint, are greater than removal costs in OUs 1 and 3, and equivalent to removal costs in OU 4.

- The capping design offered by the Panel Report did not consider addition of a foundation layer, nor incorporate any safety factors. Based on engineering

judgment and experience at other sites, the API Panel cap thickness requires an additional 8 to 12 inches.

- When the technical adjustments to the cap design are applied, along with an accounting for the larger remedial footprint, the cost of the API Panel cap is either greater than, or equivalent to the cost of removal in all OUs.

## PURPOSE

This White Paper re-evaluates the costs developed and presented within the Proposed Plan prepared by the WDNR and EPA, with those proposed by the API Panel and presented as part of the Panel Report dated January 17, 2002 (The Johnson Company, 2002). In order to understand the similarities and differences between the two plans, it is necessary to establish a comparable level of costs. This White Paper provides that basis of comparison.

The Panel Report compares costs for its proposed alternative with those presented in the Proposed Plan. However, a direct comparison of cost is not applicable; Panel Report assumes a residual risk level that is up to four times greater than that proposed by WDNR (see *White Paper No. 5A – Responses to the API Panel Report*). The API Panel proposed to manage risks to an effective RAL of 5 mg/kg (5 ppm) total PCBs in sediments, whereas the Proposed Plan used an RAL of 1 ppm. The practical result of this decision is that the Panel Report develops costs for an area that is only one-half of that managed by the Proposed Plan.

In addition, the Panel Report did not take into consideration the necessary risk, technical design considerations, and regulatory requirements that have been required at other capping sites throughout North America. These risk, technical, and regulatory-related omissions in the API Panel-proposed cap design are documented in *White Paper No. 5A – Responses to the API Panel Report* (WDNR, 2002a), *White Paper No. 6A – Comments on the API Panel Report* (Palermo, 2002), *White Paper No. 6B – In-situ Capping as a Remedy Component for the Lower Fox River* (Palermo et al., 2002), and *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits* (WDNR, 2002b). Thus, the costs reported by the API Panel do not reflect these considerations, as well.

This White Paper, then, provides for a common base comparison of costs.

## PROCEDURE

The basis for these cost comparisons come from the FS (RETEC, 2002), technical discussions in the API Panel's *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay*, and the *Cost Analysis, Ecosystem-Based Rehabilitation Plan* dated January 17, 2002 (The Johnson Company, 2002). The basis for WDNR's understanding of the Panel Report's costs are listed in Addendum 1 to this White Paper. In addition, the following assumptions are applicable:

- *White Paper No. 7 – Lower Fox River Dredged Sediment Process Wastewater Quality and Quantity: Ability to Achieve Compliance with Water Quality Standards and Associated WPDES Permit Limits* (WDNR, 2002b), documents that there are no effective water quality limits that would limit water treatment in a removal alternative. Therefore, the costs of treating water proposed in the FS, which are equivalent to those used in the two demonstration projects, are effective and viable.

- The Panel Report develops a technical basis and cost for a capping action that fits within the remedial footprint developed on an effective RAL of 5 ppm. The Proposed Plan uses an RAL of 1 ppm to achieve risk reduction. This White Paper compares costs at both action levels.

- The costs presented in the API Panel's analysis did not necessarily match up with the cap designs presented in the body of the technical Panel Report. The costs used in this White Paper reflect those developed in the Cost Analysis.

- The Panel Report describes a design basis for arriving at an effective cap thickness that included both an isolation layer and an armor layer where appropriate. While the procedure described appears to follow United States Army Corps of Engineers (USACE) guidance, the Panel Report did not offer any of the models for review, and thus there was no way to verify the accuracy of the design basis. For the purpose of this analysis, their design basis is assumed to be valid. Critique of the API Panel's design basis is left to *White Paper No. 6A – Comments on the API Panel Report* (Palermo, 2002).

- The API Panel did not report any contingency or potential range of costs associated with their estimates. Therefore, the costs presented here also do not consider contingency or range.

## RESULTS

### Risk-Related Cost Comparison

As noted in *White Paper No. 5A – Responses to the API Panel Report* (WDNR, 2002a), the Panel Report used an alternate Surface-Weighted Average Concentration (SWAC) based not upon risk considerations, but on so-called engineering considerations. The Panel Report in effect applied an RAL of 5 ppm, whereas the Proposed Plan uses 1 ppm. Table 1 compares the API Panel-reported costs for OUs 1, 3, and 4, with the costs reported in the FS. In this White Paper, only the capping alternatives (Alternative F), and the dredge and disposal options (Alternatives C1–C3) from the FS are shown for the three reaches at both the 1 and 5 ppm RAL.

## TABLE 1 COMPARISON OF THE PANEL REPORT COST ESTIMATE FOR THE 5 PPM RAL WITH THE FS COST ESTIMATE AT BOTH 1 AND 5 PPM RAL

| River Reach | Alternative | Proposed Plan SWAC [1] | API Panel SWAC [2] | API Panel Estimated Costs [3] | Feasibility Study Costs [4] | |
|---|---|---|---|---|---|---|
| | | | | | 1,000 ppb [5] | 5,000 ppb [6] |
| Little Lake Butte des Morts (OU 1) | Cap to Maximum Extent Possible (F) | 185 | 709 | $66,502,368 | $90,500,000 | $66,200,000 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | 185 | | | $116,700,000 | $48,500,000 |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C2) | 185 | | | $66,200,000 | $28,300,000 |
| Little Rapids to De Pere (OU 3) | Cap to Maximum Extent Possible (F) | 264 | 563 | $32,876,896 | $62,900,000 | $34,700,000 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | 264 | | | $95,100,000 | $38,100,000 |
| | Hydraulic Dredge, Pipeline Transfer, Combined Passive Dewatering/Landfill (C2A) | 264 | | | $43,900,000 | $32,400,000 |
| | Hydraulic Dredge, Pipeline Transfer, Separate Passive Dewatering/Landfill (C2B) | 264 | | | $99,900,000 | $65,300,000 |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C3) | 264 | | | $69,100,000 | $28,400,000 |
| De Pere to Green Bay (OU 4) | Cap to Maximum Extent Possible (F) | 156 | 706 | $133,633,847 | $357,100,000 | $234,400,000 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | 156 | | | $660,600,000 | $511,100,000 |
| | Hydraulic Dredge, Pipeline Transfer, Combined Passive Dewatering/Landfill (C2A) | 156 | | | $173,500,000 | $138,700,000 |
| | Hydraulic Dredge, Pipeline Transfer, Separate Passive Dewatering/Landfill (C2B) | 156 | | | $491,800,000 | $388,000,000 |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C3) | 156 | | | $513,500,000 | $397,200,000 |

**Notes:**

1 SWAC corresponds to RAL of 1,000 ppb.
2 API Panel SWAC represents the re-calculated value as detailed in White Paper No. 5A.
3 API Panel-reported costs correspond to capping with no dredging.
4 Costs reported in the FS. Contingency costs are not included.
5 RAL proposed in the Proposed Plan.
6 RAL corresponding to API Panel SWAC.

The cost to implement any of the FS alternatives in OUs 1 and 3 (capping or removal), are less than those proposed by the API Panel, when compared at an equivalent level of risk reduction (5 ppm). In essence, at this action level, it is less expensive to permanently remove the PCB-contaminated sediments than it is to isolate them under a cap. At the 1 ppm RAL, the removal and landfill alternative (C2) for OU 1 is roughly equivalent to the Panel Report cost for 5 ppm. For OU 3, the capping or removal alternatives are generally more expensive than those estimated for the API Panel alternative.

For OU 4, the Panel Report alternative is generally less than the FS alternative costs at both the 1 and 5 ppm levels. However, at 5 ppm the hydraulic removal with combined passive dewatering and landfilling (Alternative C2A) is approximately 3 percent more than the API Panel alternative. At 1 ppm, that same removal alternative is within 23 to 25 percent of the API Panel alternative for both OUs 3 and 4.

To compare the API Panel alternative with those developed for the Proposed Plan, it was necessary to adjust the API Panel costs for the 1 ppm RAL footprint. As shown in Table 2, the number of acres within the 1 ppm RAL footprint are 1.7 to 2.7 times greater than the 5 ppm RAL used by the API Panel. As noted above, unit costs were developed on a per-acre basis for capping from the Panel Report. The cost of wetland development and monitoring were not figured into these bulk estimates. The unit costs were then multiplied by the number of acres within the 1 ppm RAL.

## TABLE 2 ADJUSTING THE PANEL REPORT CAPPING COSTS TO THE 1 PPM RAL

| Reach | Remedial Footprint (acres) | Reported Costs | Minus Monitoring and Wetland Costs | Cost/Acre |
|---|---|---|---|---|
| ***Panel Report Costs within the 5 ppm RAL Footprint*** | | | | |
| Little Lake Butte des Morts (OU 1) | 240 | $66,502,368 | $52,354,045 | $218,142 |
| Little Rapids to De Pere (OU 3) | 120 | $32,876,896 | $25,899,529 | $215,829 |
| De Pere to Green Bay (OU 4) | 600 | $133,633,847 | $123,136,725 | $205,228 |
| ***Panel Report Costs Adjusted to the 1 ppm RAL Footprint*** | | | | |
| Little Lake Butte des Morts (OU 1) | 526 | $114,742,615.29 | | |
| Little Rapids to De Pere (OU 3) | 328 | $70,792,045.93 | | |
| De Pere to Green Bay (OU 4) | 1034 | $212,205,622.75 | | |

Table 3 compares the adjusted cost for the API Panel alternative with those developed for the FS at 1 ppm. Of importance to note is that at 1 ppm, the API Panel costs are double what they present in their Panel Report for 5 ppm. When compared to the 1 ppm RAL, the cost for permanent removal of PCB-contaminated sediments from the River is less expensive than the capping alternative proposed by the API Panel in OUs 1 and 3. For OU 4, the cost for removal versus capping is approximately equivalent at the 1 ppm RAL.

## TABLE 3 COMPARISON OF THE PANEL REPORT COST ESTIMATE FOR THE 5 PPM RAL, ADJUSTED TO THE 1 PPM RAL, AND ADJUSTED FOR TECHNICAL CORRECTIONS TO THE DESIGN, AS COMPARED WITH THE FS COST ESTIMATE AT THE 1 PPM RAL

| River Reach | Feasibility Study Alternatives | API Panel-Estimated Costs for the 5 ppm RAL | API Panel-Estimated Costs for the 1 ppm RAL | Feasibility Study Costs (1,000 ppb) | Technical Corrections to the API Panel-Estimated Cost for the 5 ppm RAL |
|---|---|---|---|---|---|
| Little Lake Butte des Morts (OU 1) | Cap to Maximum Extent Possible (F) | $66,502,368 | $114,742,615 | $90,500,000 | $90,297,613 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | | | $116,700,000 | |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C2) | | | $66,200,000 | |
| Little Rapids to De Pere (OU 3) | Cap to Maximum Extent Possible (F) | $32,876,896 | $70,792,046 | $62,900,000 | $41,761,957 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | | | $95,100,000 | |
| | Hydraulic Dredge, Pipeline Transfer, Combined Passive Dewatering/Landfill (C2A) | | | $43,900,000 | |
| | Hydraulic Dredge, Pipeline Transfer, Separate Passive Dewatering/Landfill (C2B) | | | $99,900,000 | |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C3) | | | $69,100,000 | |
| De Pere to Green Bay (OU 4) | Cap to Maximum Extent Possible (F) | $133,633,847 | $212,205,623 | $357,100,000 | $193,508,434 |
| | Hydraulic Dredge, Passive Dewatering, and Off-site Disposal (C1) | | | $660,600,000 | |
| | Hydraulic Dredge, Pipeline Transfer, Combined Passive Dewatering/Landfill (C2A) | | | $173,500,000 | |
| | Hydraulic Dredge, Pipeline Transfer, Separate Passive Dewatering/Landfill (C2B) | | | $491,800,000 | |
| | Hydraulic Dredge, Mechanical Dewatering, and Off-site Disposal (C3) | | | $513,500,000 | |

## Technical Correction to the API Panel Cap Design

In addition to comparing the costs on an equivalent risk basis, it is important to ensure that costs incorporate the state-of-the-science engineering and regulatory considerations for the design. As discussed in *White Paper No. 6A – Comments on the API Panel Report* (Palermo, 2002), the Panel Report states that it utilizes the models developed by the USACE for designing a cap, but does not provide any means for checking parameters or results for those models (i.e., there is no way to verify the API Panel's calculations). While acknowledging this fact, based upon experience at other capping sites (see *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* [Palermo et al., 2002]) and professional experience, the API Panel's proposed cap design is too thin for adequate chemical isolation. Furthermore, the design does not incorporate losses to the underlying sediments during cap placement (foundation layer), nor does it incorporate any kind of safety factor into the overall design. As noted in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* (Palermo et al., 2002), experience at other capping sites has shown that up to 4 inches of additional sand is needed to account for the foundation layer, and that a safety factor of 1.5 times the isolation design is recommended for the Lower Fox River.

Table 4 shows the effective cap thickness after application of these technical corrections. Table 4 assumes, without verification, that the isolation layer of sand and the armor requirements estimated by the Panel Report are valid. Table 4 applies a 4-inch foundation layer and a 1.5 safety factor to the total sand application to achieve total cap thickness of 24, 21, and 24 inches for OUs 1, 3, and 4, respectively.

Table 5 presents the incremental increase in cost for adding additional layers of sand to the cap for chemical isolation. These costs were determined using the same assumptions and numbers that are listed in the Panel Report's Cost Analysis, and are only for the 5 ppm RAL footprint. As can be seen on Figure 1, the costs are relatively linear and add 3 to 4 percent per inch of additional isolation layer. The required effective cap thickness for each of the OUs is highlighted in Table 5 and increase the Panel Report costs by 27 to 45 percent. When compared then to the cost at the 1 ppm RAL (Table 3), the removal alternatives in the WDNR and EPA's Proposed Plan are still favorable to capping in OUs 1 and 3, and comparable to capping in OU 4. If these costs are then adjusted by a factor of 2 to account for the larger area within the 1 ppm RAL (see Table 2), the removal alternatives in all OUs are more cost effective than those proposed in the Panel Report.

## TABLE 4 CORRECTION OF THE API PANEL CAP DESIGN TO ACCOUNT FOR FOUNDATION LAYER AND SAFETY FACTOR

| River Reach | Effective Isolation Cap Thickness | | | | API Panel Armor Layer | Total Cap Thickness |
|---|---|---|---|---|---|---|
| | Foundation Layer | API Panel-Estimated Isolation Layer | Subtotal | Safety Factor of 1.5 | | |
| Little Lake Butte des Morts (OU 1) | 4 | 11.5 | 15.5 | 23.25 | 0.5 | 23.75 |
| Little Rapids to De Pere (OU 3) | 4 | 6 | 10 | 15 | 6 | 21 |
| De Pere to Green Bay (OU 4) | 4 | 12 | 16 | 24 | 0 | 24 |

**Notes:**

[1] Foundation layer is 4 inches of placed material that mixes with the underlying sediments.

[2] API Panel-estimated isolation layer is the thickness of sand cap (fine + medium + coarse fractions) as reported in Cost Analysis addendum to the Panel Report.

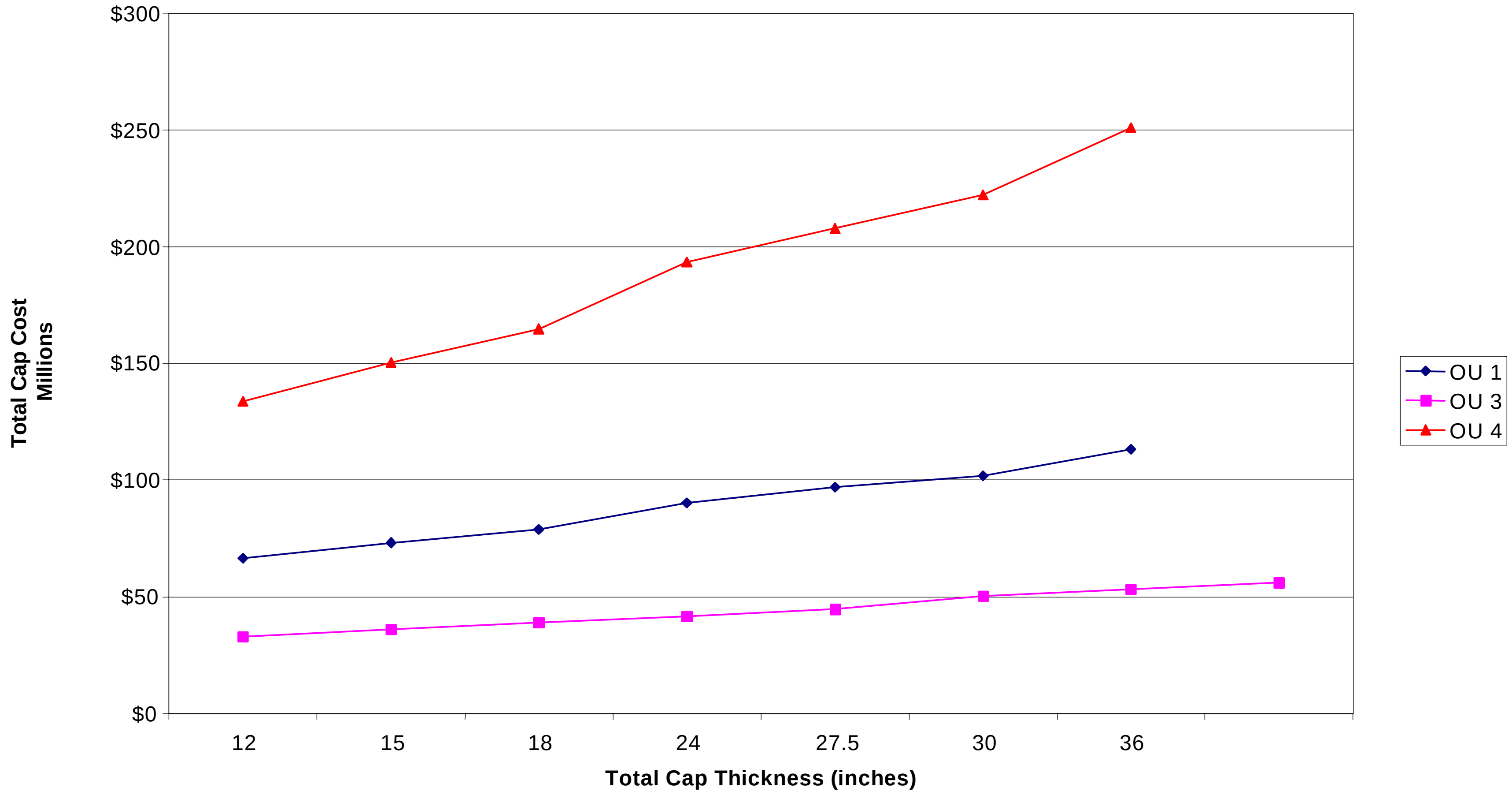
[3] A safety factor of 1.5 times the total sand thickness is applied as recommended in Palermo and Thompson (*White Paper No. 6A – Comments on the API Panel Report* [Palermo, 2002]).

[4] API Panel armor layer is as reported in the Cost Analysis addendum to the Panel Report.

## TABLE 5 INCREMENTAL INCREASE IN THE PANEL REPORT COSTS ASSOCIATED WITH INCREASING THE THICKNESS OF THE CHEMICAL ISOLATION LAYER

| Reach | API Panel Design Basis | | | Alternative Design Basis | | Incremental Cost Increase | | | Percent Increase |
|---|---|---|---|---|---|---|---|---|---|
| | Fine Sand | Coarse Sand | Gravel | Incremental Medium Sand Addition | Total Cap Thickness | API Panel Cost | Incremental Increase | Final Cost | |
| Little Lake Butte des Morts (OU 1) | 2.2 | 9.3 | 0.5 | 0 | 12 | $66,502,368 | $0 | $66,502,368 | 0% |
| | 2.2 | 9.3 | 0.5 | 3 | 15 | $66,502,368 | $6,574,424 | $73,076,792 | 10% |
| | 2.2 | 9.3 | 0.5 | 6 | 18 | $66,502,368 | $12,314,697 | $78,817,065 | 19% |
| | 2.2 | 9.3 | 0.5 | 12 | 24 | $66,502,368 | $23,795,245 | $90,297,613 | 36% |
| | 2.2 | 9.3 | 0.5 | 15.5 | 27.5 | $66,502,368 | $30,492,231 | $96,994,599 | 46% |
| | 2.2 | 9.3 | 0.5 | 18 | 30 | $66,502,368 | $35,275,792 | $101,778,160 | 53% |
| | 2.2 | 9.3 | 0.5 | 24 | 36 | $66,502,368 | $46,756,339 | $113,258,707 | 70% |
| Little Rapids to De Pere (OU 3) | 3 | 3 | 6 | 0 | 12 | $32,876,896 | $0 | $32,876,896 | 0% |
| | 3 | 3 | 6 | 3 | 15 | $32,876,896 | $3,144,787 | $36,021,683 | 10% |
| | 3 | 3 | 6 | 6 | 18 | $32,876,896 | $6,014,924 | $38,891,820 | 18% |
| | 3 | 3 | 6 | 9 | 21 | $32,876,896 | $8,885,061 | $41,761,957 | 27% |
| | 3 | 3 | 6 | 12 | 24 | $32,876,896 | $11,755,197 | $44,632,093 | 36% |
| | 3 | 3 | 6 | 18 | 30 | $32,876,896 | $17,495,471 | $50,372,367 | 53% |
| | 3 | 3 | 6 | 21 | 33 | $32,876,896 | $20,365,608 | $53,242,504 | 62% |
| | 3 | 3 | 6 | 24 | 36 | $32,876,896 | $23,235,745 | $56,112,641 | 71% |
| De Pere to Green Bay (OU 4) | 6 | 6 | 0 | 0 | 12 | $133,633,847 | $0 | $133,633,847 | 0% |
| | 6 | 6 | 0 | 3 | 15 | $133,633,847 | $16,822,534 | $150,456,381 | 13% |
| | 6 | 6 | 0 | 6 | 18 | $133,633,847 | $31,173,218 | $164,807,065 | 23% |
| | 6 | 6 | 0 | 12 | 24 | $133,633,847 | $59,874,587 | $193,508,434 | 45% |
| | 6 | 6 | 0 | 15 | 27 | $133,633,847 | $74,225,271 | $207,859,118 | 56% |
| | 6 | 6 | 0 | 18 | 30 | $133,633,847 | $88,575,955 | $222,209,802 | 66% |
| | 6 | 6 | 0 | 24 | 36 | $133,633,847 | $117,277,323 | $250,911,170 | 88% |

**Figure 1 Increase in Costs with Incremental Increase in Cap Thickness**



## CONCLUSIONS

Based upon this analysis, the following conclusions can be drawn:

- The Panel Report does not accurately portray comparable remedial costs. The Panel Report compares its alternative, a less protective RAL (5 ppm) with the Proposed Plan RAL (1 ppm).
- When compared at the same RAL (5 ppm), contaminated sediment removal alternatives in the FS are less expensive, or equivalent, in cost to the API Panel plan for all three OUs.
- The Proposed Plan removal alternative for OU 1 (dredge with off-site disposal), at an RAL of 1 ppm is equivalent in cost to the API Panel capping alternative.
- The Proposed Plan removal alternative for OUs 3 and 4 achieve permanent removal of PCBs from the River at a lower (more protective) RAL, but are within 23 to 25 percent of the costs proposed by the Panel Report.
- The Panel Report costs, when projected onto the 1 ppm RAL footprint, are greater than removal costs in OUs 1 and 3, and equivalent to removal costs in OU 4.
- The capping design offered by the Panel Report did not consider addition of a foundation layer, nor incorporate any safety factors. Based on engineering judgment and experience at other sites, the API Panel cap thickness requires an additional 8 to 12 inches.
- When the technical adjustments to the cap design are applied, along with an accounting for the larger remedial footprint, the cost of the API Panel cap is either greater than, or equivalent to the cost of removal in all OUs.

## REFERENCES

Palermo, M. R., 2002. *White Paper No. 6A – Comments on the API Panel Report*. Wisconsin Department of Natural Resources, Madison, Wisconsin. December.

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# ADDENDUM 1
# BASIS FOR COST EVALUATION

The following steps summarize the cost analysis performed to include additional coarse sand in the subaqueous cap proposed by the API Panel for Lower Fox River OUs 1, 3, and 4. WDNR referred to the document *Cost Analysis, Ecosystem-Based Rehabilitation Plan* dated January 17, 2002 to obtain the unit costs for calculations (Panel Report).

## Little Lake Butte des Morts (OU 1)

1) Proposed Capping Area = 240 acres

2) Breakdown of API Panel-Proposed 12-inch Cap:

    a) Fine Sand (quartz) = 1.7 inches
    b) Medium Sand (quartz) = 0.5 inch
    c) Coarse Sand (quartz) = 9.3 inches
    d) Fine Gravel (limestone) = 0.5 inch

3) Area in Square Feet ($ft^2$) = 240 acres × 43,560 $ft^2$/acre = 10,454,400

4) Additional Volume of Coarse Sand (quartz/limestone) Required (12 inches of coarse sand) = 10,454,400 $ft^2$ × 1 ft × 1 cubic yards (cy)/27 cubic feet ($ft^3$) × 1.4 tons/cy = 542,080 tons

5) From Panel Report, Capping Placement Rate = 1,150 tons/day

6) Additional Number of Days Required for Capping = 542,080 tons/1,150 tons/day = 471 days

7) Therefore, Additional Costs Include:

    a) Cap Placement = 471 days × $25,454/day = $11,988,834
    b) Sand Procurement – Material/Delivery/Tax = 542,080 tons × $17.14/ton = $9,292,251
    c) Cap Placement QA/Bathymetry = 471 days × $ 3,546/day = $1,670,166
    d) Mobilization/Demobilization = 2 seasons = 2 × $210,473 = $420,946
    e) Silt Curtain = 2 seasons = 2 × $64,177 = $128,354
    f) Winterization of Four Cap Barges = 2 seasons = 2 × $142,425 = $248,850

8) Total Additional Costs Due to Additional 12-inch Coarse Sand Cap Layer = $23,749,401

9) Total Cost (not inflated) Proposed in the Panel Report for 12-inch Subaqueous Cap = $66,502,368

10) Final Cost after Adding Additional Costs for 12-inch Coarse Sand Cap = $90,251,769

11) Total Cost Increase Due to Addition of 12-inch Coarse Sand Cap = 36%

## Little Rapids to De Pere (OU 3)

1) Proposed Capping Area = 120 acres

2) Breakdown of API Panel-Proposed 12-inch Cap:

   a) Fine Sand (quartz) = 0.6 inch
   b) Medium Sand (limestone) = 0.6 inch
   c) Medium Sand (quartz) = 2.4 inches
   d) Coarse Sand (limestone) = 2.4 inches
   e) Fine Gravel (limestone) = 1.2 inches
   f) Coarse Gravel (quartz) = 4.8 inches

3) Area in Square Feet = 120 acres × 43,560 $ft^2$/acre = 5,227,200

4) Additional Volume of Coarse Sand (quartz/limestone) Required (12 inches of coarse sand) = 5,227,200 $ft^2$ × 1 ft × 1 cy/27 $ft^3$ x 1.4 tons/cy = 271,040 tons

5) From Panel Report, Capping Placement Rate = 1,150 tons/day

6) Additional Number of Days Required for Capping = 271,040 tons/1,150 tons/day = 236 days

7) Therefore, Additional Costs Include:

   a) Cap Placement = 236 days × $25,454/day = $6,007,144
   b) Sand Procurement – Material/Delivery/Tax = 271,040 tons × $17.14/ton = $4,645,626
   c) Cap Placement QA/Bathymetry = 236 days × $ 3,546/day = $836,856
   d) Mobilization/Demobilization = 1 season = 1 × $210,473 = $210,473
   e) Silt Curtain = 1 season = 1 × $64,177 = $64,177

8) Total Additional Costs Due to Additional 12-inch Coarse Sand Cap Layer = $11,764,276

9) Total Cost (not inflated) Proposed in the Panel Report for 12-inch Subaqueous Cap = $32,876,896.

10) Final Cost after Adding Additional Costs for 12-inch Coarse Sand Cap = $44,641,172

11) Total Cost Increase Due to Addition of 12-inch Coarse Sand Cap = 36%

## De Pere to Green Bay (OU 4)

1) Proposed Capping Area = 600 acres

2) Breakdown of API Panel-Proposed 12-inch Cap – There are several combinations proposed for OU 4, as listed below:

   a) 6-inch Coarse Sand and 6-inch Fine Sand

   b) 6-inch Fine Gravel, 3-inch Medium Sand, and 3-inch Fine Sand
   c) 6-inch Medium Sand and 6-inch Fine Sand

3) Area in Square Feet = 600 acres × 43,560 $ft^2$/acre = 26,136,000

4) Additional Volume of Coarse Sand (quartz/limestone) Required (12 inches of coarse sand) = 26,136,000 $ft^2$ × 1 ft × 1 cy/27 $ft^3$ × 1.4 tons/cy = 1,355,200 tons

5) From Panel Report, Capping Placement Rate = 1,150 tons/day

6) Additional Number of Days Required for Capping = 1,355,200 tons/1,150 tons/day = 1,178 days

7) Therefore, Additional Costs Include:

   a) Cap Placement = 1,178 days × $25,454/day = $29,984,812
   b) Sand Procurement – Material/Delivery/Tax = 1,355,200 tons × $17.14/ton = $23,228,128
   c) Cap Placement QA/Bathymetry = 1,178 days × $ 3,546/day = $4,177,188
   d) Mobilization/Demobilization = 9 seasons = 9 × $210,473 = $1,894,257
   e) Silt Curtain = 9 seasons = 9 × $64,177 = $577,593

8) Total Additional Costs Due to Additional 12-inch Coarse Sand Cap Layer = $59,861,978

9) Total Cost (not inflated) Proposed in the Panel Report for 12-inch Subaqueous Cap = $133,633,847

10) Final Cost after Adding Additional Costs for 12-inch Coarse Sand Cap = $193,495,825

11) Total Cost Increase Due to Addition of 12-inch Coarse Sand Cap = 45%

# White Paper No. 5C – Evaluation of Remedial Alternatives for Little Lake Butte des Morts Proposed by WTMI and P.H. Glatfelter

***Response to a Document by CH2M HILL***

## Focused Feasibility Study for Operable Unit 1 Lower Fox River Site

2002

***and***

***Response to a Document by Blasland, Bouck, and Lee, Inc.***

## Little Lake Butte des Morts Deposit A/B Remediation Proposal

January 21, 2002

***This Document has been Prepared by***

Wisconsin Department of Natural Resources

**December 2002**

# WHITE PAPER NO. 5C –
# EVALUATION OF REMEDIAL ALTERNATIVES FOR
# LITTLE LAKE BUTTE DES MORTS
# PROPOSED BY WTMI AND P.H. GLATFELTER

## ABSTRACT

This White Paper evaluates the remedial proposals presented by WTMI Company (formerly Wisconsin Tissue Mills, Inc.) and P.H. Glatfelter (PHG) for Operable Unit 1 (OU 1) of the Lower Fox River (Little Lake Butte des Morts). WTMI's proposals are contained in the document entitled *Focused Feasibility Study for Operable Unit 1, Lower Fox River Site* (CH2M HILL, 2002), and PHG's remedial proposal, defined in the *Little Lake Butte des Morts Deposit A/B Remediation Proposal* (BBL, 2002). Both proposals appear to have been developed in tandem, and with consideration of the Appleton Paper, Inc. (API) Panel Report entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (Panel Report) (The Johnson Company, 2002) (see *White Paper No. 5A – Responses to the API Panel Report* and *White Paper No. 5B – Evaluation of API Capping Costs Report*). The central tenant for their proposal is that active remediation is only required for Deposit A/B, portions of Deposit POG, and that active remediation for the remainder of OU 1 is not required.

The following conclusions are presented in this White Paper:

- The WTMI and PHG remedial proposals do not provide a level of risk reduction equivalent to the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001). The combined proposals would allow for a continued level of risk that is a full order of magnitude greater than that set by the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA).

- The WTMI and PHG proposal includes natural attenuation for Deposit E, which is not supported by the data and does not include the recommendations of the API Panel that stated that natural attenuation will not result in acceptable levels of risk reduction in a reasonable timeframe.

- The concept-level remedial proposals are technically feasible and implementable. The dredge proposal is equivalent to that conducted at Sediment Management Unit (SMU) 56/57, including dredge rates and water treatment equivalent what was done at the demonstration projects. The WTMI and PHG proposals do not include the water treatment restrictions listed by the API Panel.

- The proposed cap designs are not based upon site-specific engineering considerations, and are likely inadequate for their intended purpose.

- The WTMI proposal includes capping within a federal navigation channel, which will require an Act of Congress to permit.

- Neither the WTMI or PHG proposal considers long-term operating, monitoring, maintenance, institutional controls, or fiduciary responsibilities.

- The habitat benefits purported by the respective plans cannot be achieved with the proposed capping materials at those specific locations.

## PURPOSE

This White Paper evaluates the remedial proposals represented by WTMI and PHG for OU 1 of the Lower Fox River (Little Lake Butte des Morts). The proposals developed by WTMI and PHG are presented in their respective comments to the Proposed Plan (WDNR and EPA, 2001). Both proposals appear to have been developed in tandem, and with consideration of the Panel Report (The Johnson Company, 2002). The central tenant for their proposal is that active remediation is only required for Deposit A/B, portions of Deposit POG, and that active remediation for the remainder of OU 1 is not required.

This White Paper evaluates the combined proposal for OU 1 relative to risk reduction, technical feasibility, barriers to implementation, and potential alterations to habitat.

## DESCRIPTION OF THE WTMI/PHG ALTERNATIVES

WTMI's proposals are contained in the document entitled *Focused Feasibility Study for Operable Unit 1, Lower Fox River Site* (CH2M HILL, 2002). WTMI proposed to actively manage only those areas defined as "hot spots." "Hot Spots" are defined as surface sediments (0 to 10 cm) with polychlorinated biphenyl (PCB) concentrations that exceed 10 milligrams per kilogram (mg/kg). According to the WTMI document, only Deposit A/B, the southwest area in Deposit POG, and the northern position within the federal navigation channel of POG meet that criterion. WTMI's remedial action would be limited to the hot spots at Deposit POG. Three specific alternatives were proposed:

- Dredge surficial sediment hot spots with off-site disposal;

- Dredge surficial sediment hot spots to a nearshore confined disposal facility constructed at Arrowhead Park; and

- Cap surficial sediment hot spots using 6 inches of sand for isolation and 6 inches of fine gravel to provide hydraulic stability.

WTMI's apparent preferred remedy is the capping alternative.

PHG's remedial proposal, defined in the *Little Lake Butte des Morts Deposit A/B Remediation Proposal* (BBL, 2002), is confined solely to Deposit A/B in the south end of OU 1. The proposal would remove sediments where the surface PCB concentrations exceeded 10 mg/kg, down to “depths necessary” to remove all sediments greater than 10 mg/kg. There is insufficient information provided to determine “depths necessary.” Removal, dewatering, and water treatment would follow the same as those that occurred during the demonstration projects at Deposit N and SMU 56/57. The proposal describes the dredge and disposal of 32,500 cubic yards (cy), of which approximately 1,000 cy would require disposal in a Toxic Substances Control Act (TSCA) facility. Dredged areas would be backfilled with 6 inches of sand to promote “establishment of aquatic habitat.” Areas within Deposit A/B that are greater than 1 mg/kg, but less than 10 mg/kg, will be covered with a 6-inch sand layer, and where “appropriate,” a gravel/cobble armoring layer would be laced to prevent erosion and habitat enhancement.

Both WTMI and PHG in their respective reports make the assertion that the combined efforts at deposits A/B and POG will result in a surface-weighted average concentration (SWAC) below 1 mg/kg. For OU 1, the capping areas correspond to those areas where PCB concentrations were greater than 5 mg/kg, with the exception that the API Panel did propose capping a larger section of Deposit E that included some portions where concentrations exceeded 1 mg/kg.

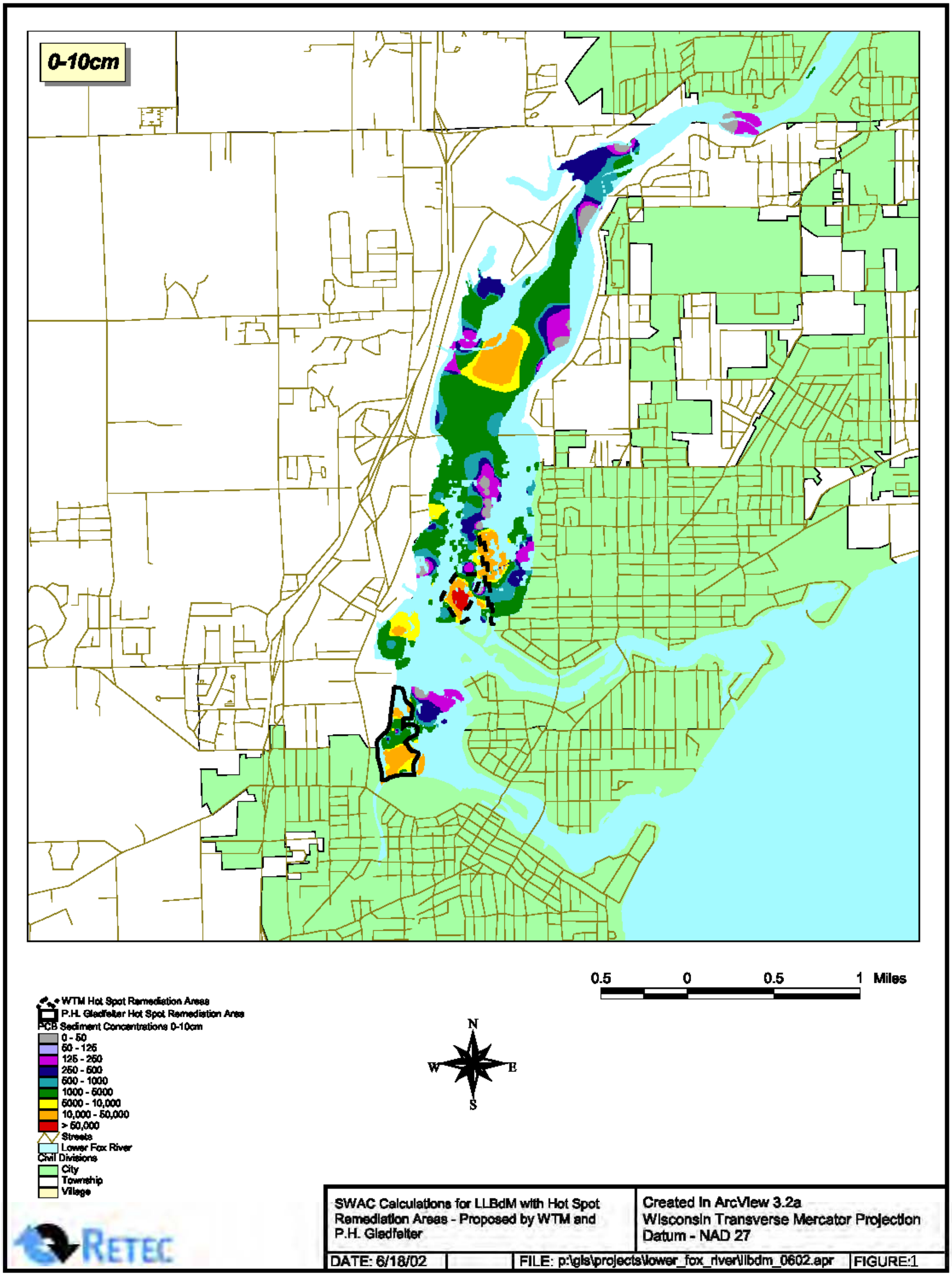
## EVALUATION OF RISK REDUCTION

The WTMI/PHG proposal allows for a higher level of risk than that listed in the Proposed Plan. To be protective of both recreational and high-intake fish consumers, WDNR and the EPA established a reasonable maximum exposure (RME) cancer risk of 1 in 100,000, or $10^{-5}$, in the Proposed Plan. To achieve that, the Proposed Plan defined a Remedial Action Level (RAL) of 1 mg/kg. The WTMI report lists a target RME of $10^{-4}$, which is an order of magnitude less stringent than that defined by the resource agencies. Without developing or defending a specific argument, both proposals state that the *de facto* RAL is 10 mg/kg. This order of magnitude difference is reflected throughout the entire risk reduction evaluation.

Risk reduction within the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a) and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and the Proposed Plan is directly tied to reducing exposure of benthic organisms and fish to PCBs in the sediments of OU 1. The relationship between sediment concentrations of PCBs and their direct link to risks were documented within the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c). Both the Proposed Plan and the Panel Report (The Johnson Company, 2002) embraced the concept of SWAC as the appropriate metric for surface sediment PCB reduction. A range of RALs were formulated in the FS, and from those the WDNR and EPA selected an RAL of 1 mg/kg to achieve a SWAC of 0.19 mg/kg for OU 1. The relationship between the RAL, the SWAC, and risk reduction is described in detail in *White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River* (WDNR, 2002a).

The API Panel proposed that a SWAC of 0.5 mg/kg be used as a design criterion. The API-proposed SWAC was not based on a site-specific assessment of risk, but rather on an engineering "implementation efficiency" estimation, and the API Panel developed their proposed capping areas and their report on that SWAC. Neither WTMI nor PHG went through an analysis similar to the API Panel; rather they appeared to focus solely on alternatives to deposits A/B and POG. This section compares the WTMI/PHG SWAC to those defined by both the Proposed Plan and the Panel Report.

Methods for recalculating the SWAC are defined in *White Paper No. 5A – Responses to the API Panel Report* (WDNR, 2002b). The three remediation areas proposed by WTMI and PHG include Deposit A, the southwestern area in Deposit POG, and the northern portion of the navigation channel in Deposit POG (Figure 1). These three proposed remediation areas were digitized from the figures presented in the two reports, and imported into ArcView GIS software. Upon overlaying the digitized remediation areas on the interpolated PCB concentration maps, adjustments were made as needed to the location of the areas to the best extent possible to match the remediation areas specified by WTMI and PHG. Upon overlaying the WTMI-proposed remediation areas on the interpolated PCB concentration map, SWAC calculations were completed.


0-10cm
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N
W
E
S
WTM Hot Spot Remediation Areas
P.H. Gladfelter Hot Spot Remediation Area
PCB Sediment Concentrations 0-10cm
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 5000
5000 - 10,000
10,000 - 50,000
> 50,000
Streets
Lower Fox River
Civil Divisions
City
Township
Village
RETEC
SWAC Calculations for LLBdM with Hot Spot Remediation Areas - Proposed by WTM and P.H. Gladfelter
Created in ArcView 3.2a
Wisconsin Transverse Mercator Projection
Datum - NAD 27
DATE: 6/18/02
FILE: p:\gis\projects\lower_fox_river\llbdm_0602.apr
FIGURE:1

Table 1 compares the Proposed Plan SWAC at the 1 mg/kg RAL with those proposed by the API and by WTMI/PHG. Those SWACs are 0.19, 0.71, and 1.7 mg/kg, respectively. The WTMI/PHG remedial proposal results in a risk level that is twice that proposed by the API Panel, and an order of magnitude greater than at presented in the Proposed Plan. Essentially, the WTMI/PHG proposes an RAL of greater than 10 mg/kg to achieve a SWAC of 1.7 mg/kg.

## TABLE 1 COMPARISON OF PROPOSED PLAN RAL AND SWAC WITH THOSE PROPOSED BY THE API PANEL AND BY WTMI/PHG FOR OPERABLE UNIT 1 (ALL UNITS IN MG/KG)

| Proposed Plan | | API Panel | | WTMI/PHG | |
|---|---|---|---|---|---|
| RAL | SWAC | RAL | SWAC | RAL | SWAC |
| 1 | 0.19 | 5 | 0.71 | 10 | 1.7 |

As an additional check, the more recent sediment data submitted by WTMI and PHG were also evaluated, relative to the conclusions in the RI/FS and the Proposed Plan. *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples* (WDNR, 2002c), showed that these newer data generally support the conclusion of the RI/FS and the Proposed Plan. Surface sediments within Little Lake Butte des Morts exceed the RAL of 1,000 ppb, and do not substantively alter the current SWAC for OU 1. The Proposed Plan defined remedial actions at deposits A/B, C, POG, and E that exceeded the 1 mg/kg RAL; these newer data support that position.

## FEASIBILITY EVALUATION

At a concept level, the technical proposals for deposits A/B and POG are, in concept, feasible. Full removal, partial removal followed by application of a cap, or capping only, are all technically implementable. Both reports present solely concept-level proposals; neither presents an in-depth engineering analysis, and/or sufficient detail to examine the basis for the claims of the efficacy of alternative application.

For evaluating the dredging portion of their proposals, the WTMI/PHG evaluations propose to remove sediments in a manner consistent with the previously conducted at SMU 56/57. The PHG discussion provides more detail the WTMI, and is technically achievable. Within the discussion of dredging, the water treatment proposed is identical to that used at SMU 56/57, and makes no reference to the limits on water treatment (and hence dredging rates) limits alleged by the API Panel. The schedule specifically identified in the PHG report for that volume is achievable.

Both proposals rely on the cap thickness and design estimates provided by the Panel Report, without presenting an evaluation of post-dredge conditions. As noted in *White Paper No. 6A – Comments on the API Panel Report* (Palermo, 2002), a deficit of the API Panel capping proposal is that the API Panel did not present the rationale in selecting total cap thickness, the basis of design for the chemical isolation component, consolidation-induced advection, potential mixing of contaminated sediments and cap material, and constraints on capping in shallow water areas. There is no basis to support an engineering design for the 6-inch cap proposed by WTMI/PHG on bedded sediments, much less on sediments that have been disturbed by dredging. According to Dr. Palermo's professional judgment, even a total cap thickness of 12 inches seems non-conservative for a major Site like the Lower Fox River.

The report states that there is no indication of potential seepage (advection) due to groundwater flow, and so this was not considered in the model runs. However, the process of consolidation-induced advection will occur, and does not appear to be considered in the cap design.

## LEGAL AND REGULATORY CONSIDERATIONS

The alternative proposals for residual capping (after partial dredging), or capping, have not addressed, or do not consider the institutional/regulatory constraints associated with capping. This includes capping TSCA materials, lake bed grants, federal navigation channels, riparian owner issues, deed restrictions, fiduciary responsibility, and long-term liability. These issues are addressed in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* (Palermo et al., 2002).

Some of the specific elements from White Paper No. 6B that the WTMI/PHG proposal does not address include, but are not limited to:

- The overall remedy must manage all sediments within the 1 mg/kg contour, and should achieve a SWAC of 0.250 mg/kg.

- Capping cannot occur in designated navigation channels, with an appropriate setback in areas, which could require dredging in the future. This could occur only with an Act of Congress.

- A permanent *in-situ* capping (ISC) or residual cap will require either addressing riparian owner rights under Wisconsin Statutes Chapter 30 or a Lake Bed Grant that will require an Act from the State Legislature.

- The liability for maintenance of a capping alternative will need to be maintained in perpetuity. Some type of financial mechanism will be required that would need to cover long-term operating and maintenance, consideration for maintenance of the dams, as well as any permanent institutional controls that would need to be enforced under the plan, etc.

There is no plan or contingency allowed for any of these issues in either plan.

## HABITAT RESTORATION AND ENHANCEMENT

Both proposals indicate that habitat restoration and enhancement will occur as part of their placement of sand/gravel during capping. PHG's plan states that materials will be selected so that the resultant cap surface will create habitat that enhance the quality of benthic aquatic habitat. PHG maintains that "Other valuable habitat such as submerged aquatic vegetation beds, emergent vegetation and shoreline wetlands will be created or restored to expedite the recovery of the aquatic communities following remediation." As detailed in *White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River* (WDNR, 2002d), sand is poor substrate for benthic infaunal recolonization, or the establishment of submerged or emergent aquatic vegetation. While appropriately sized cobble can support the larval stages of emergent insects such as mayflies, caddisflies, stoneflies, or even dragonflies, these species are typically found in clear, fast-moving streams or rivers. In short, placement of sand, gravel, or cobble only would likely result in a habitat that is hostile to the very ecological communities the proposals seek to replace.

## CONCLUSIONS

The following conclusions can be drawn from this analysis:

- The WTMI/PHG remedial proposals do not provide a level of protection equivalent to the Proposed Plan. The combined proposals would allow for a continued level of risk that is a full order of magnitude greater than that determined by EPA/WDNR. Furthermore, the WTMI/PHG proposal does not even include the recommendations of the Panel Report.

- The concept-level remedial proposals are technically feasible and implementable. The dredge proposal is equivalent to that conducted at SMU 56/57, including dredge rates and water treatment equivalent what was done at the demonstration projects. The proposals apparently ignore the water treatment restrictions listed by the API Panel.

- The proposed cap designs are not based upon site-specific engineering considerations, and are likely inadequate for their intended purpose. More than 12 inches of cap will be required to achieve PCB isolation.

- The WTMI proposal includes capping within a federal navigation channel. Unless an Act of Congress is granted, this is prohibited by law.

- Neither plan considers long-term operating, monitoring, maintenance, institutional controls, or fiduciary responsibilities.

- The habitat benefits purported by the respective plans cannot be achieved with the proposed capping materials at those specific locations.

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# White Paper No. 6A – Comments on the API Panel Report

***Response to a Document by The Johnson Company***

## Ecosystem-Based Rehabilitation Plan –
## An Integrated Plan for Habitat Enhancement
## and Expedited Exposure Reduction
## in the Lower Fox River and Green Bay

January 2002

***This Document has been Prepared by***

Michael R. Palermo, Ph.D.

**December 2002**

# WHITE PAPER NO. 6A –
# COMMENTS ON THE API PANEL REPORT

## ABSTRACT

During the comment period, multiple comments were received from public and private entities both for and against capping alternatives for the Lower Fox River. Appleton Papers, Inc. (API) provided funding to assemble a panel of university professors and scientists to evaluate the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) for the Lower Fox River and Green Bay. The Appleton Paper, Inc. Panel (referred to as "the API Panel") completed a report entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (referred to herein as the "Panel Report") dated January 17, 2002 (The Johnson Company, 2002) that was submitted as part of the comments during the public response period. The Panel Report contended that the Agencies' proposed contaminated sediment removal plan would be limited by water quality discharge issues, and that risk reduction could be better achieved by capping areas of contaminated sediments within the Lower Fox River. They further purported that the capping would also result in habitat enhancement.

This White Paper is one in a series of papers that focuses on evaluating the claims of the Panel Report. Specifically, it presents an evaluation of the API Panel cap design conducted by Dr. Michael Palermo, P.E. Dr. Palermo is an internationally recognized expert in capping design and implementation. His resume is attached to this White Paper.

The White Paper finds, in general, that the Panel Report paints any overly optimistic picture for capping, and overly pessimistic one for dredging. The overall findings contained in this White Paper showed that the Panel Report did not present a rationale for its selection for total cap thickness, the basis for a design for the chemical isolation component, consolidation-induced advection, potential mixing of contaminated sediments and cap material, and constraints on capping in shallow-water areas. This White Paper analysis also concludes even a total cap thickness of 12 inches seems nonconservative; and capping could be a component of the remedy, but not the sole remedy for any reach.

## GENERAL COMMENTS

- The Panel Report contains useful information for considering potential capping and dredging remedies for this Site. For example, the discussion of the Lower Fox River discharge characteristics as compared to other rivers in the region and the use of a map format for displaying shear stress for flood events are both useful in placing erosion potential and the need for cap armor in perspective. Also, the discussion of potential constraints on dredging related to river assimilative capacity provide needed insight for the Agencies in considering less restrictive requirements or waivers, as appropriate.

- The overall recommendations in the Panel Report rely on projections of the Surface-Weighted Average Concentration (SWAC) reductions for both a full dredging remedy and a full capping remedy. But such a direct comparison is based on many assumptions, some of which are inappropriate. For example, areas proposed for capping are based on a 5 parts per million (ppm) Remedial Action Level (RAL) (proposed by the API Panel for reasons of engineering efficiency), while those assumed for dredging are based on the 1 ppm RAL in the Proposed Plan (WDNR and EPA, 2001) (chosen based on the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* [BLRA] [RETEC, 2002]). A direct comparison of SWAC reduction rates for two alternatives with differing action levels is inappropriate when those action levels drive the timeline for completion of the respective actions.

- In general, the Panel Report seems to paint an overly optimistic picture for capping and an overly pessimistic picture for dredging. The rate at which dredging is assumed to occur is severely hampered by an assumed constraint on river assimilative capacity, which would likely not be imposed on a major remedial project. In contrast, the implementation of capping is assumed to be essentially flawless in its execution and effectiveness, and potential constraints on capping which are mentioned in the Panel Report are described as non-problems.

- I generally agree with one theme evident throughout the Panel Report, that capping is a technically feasible remedy approach for the Lower Fox River. However, there are several technical and institutional constraints on the application of capping at this Site that the Panel Report does not fully consider. Based on my review, capping could be a component of a remedy, but could not be the sole remedy for any reach. A combination of some capping and dredging is likely the most efficient remedy.

- Technical issues for capping not fully considered in the Panel Report include: the rationale in selecting total cap thickness, the basis of design for the chemical isolation component, consolidation-induced advection, potential mixing of contaminated sediments and cap material, and constraints on capping in shallow water areas. A detailed design effort for any selected capping remedy should address these and all pertinent design considerations. While the Panel Report considers some design issues, the information on cap design is not clearly presented and there is insufficient information offered to verify the proposed design with respect to all the issues.

- The Panel Report has not addressed fully institutional/regulatory constraints associated with capping, such as capping Toxic Substances Control Act (TSCA) materials, lake bed grants, riparian owner issues, deed restrictions, fiduciary responsibility, and long-term liability.

- Additional details on further evaluation of an *in-situ* capping alternative for the project is presented in *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River* (Palermo, et al., 2002).

## SPECIFIC COMMENTS

Specific comments follow, grouped by general category and referenced to page and section.

### Site Characterization

**Page 6 – Conceptual Model – Flood Flow Conditions:** The Panel Report states on page 6 that since the flood flow volume per unit drainage area and the ratio of flood to average discharge for the Lower Fox River is low compared to other rivers in the region, the erosive forces due to floods would be comparatively low. The general comparisons of discharge characteristics are useful in placing the hydrodynamic characteristics of the Lower Fox River in a broader context. But the clear-cut statement that erosive force on the Lower Fox River is low is not supported by the information provided on flow ratios. Erosive force is a function of shear stress, and shear stress is a function of this particular Site geometry, sediment characteristics, and given flow events.

**Page 17 – Hydrologic Characteristics:** On page 17, the statement is made that a flow increase does not translate to a velocity increase and to a shear increase (exactly the point I wanted to make for page 6). But the text here goes further by stating that shear stress applied to Lower Fox River sediments is lower relative to similar rivers. This may be true, but the data are not presented to support this statement. Are data on bottom velocities and/or shear stresses during flood stage available for all the rivers in the region? The bottom line is the need to evaluate erosion potential for this River, and this should be evaluated based on the anticipated shear stresses on this River for selected design events. The Panel Report presents such information in Appendix A, based on the *Review of USEPA FIELDS Analysis of Bed Elevation Changes in the Lower Fox River* (Limno-Tech, 2002) modeling effort. The map format presented in Appendix A is a very useful method to depict modeling results. However, I understand there is disagreement on the appropriate modeling approach. WDNR has also conducted modeling, and there are substantive differences in how the two models interpret shear stress and resuspension. Limno-Tech's model predicts negligible shear stress, while WDNR's model predicts a far greater stress and resuspension. These differences must be resolved prior to the design phase.

### Dredging

**Page 8 – Constraints on Dredging:** The need to treat and discharge water from a conventional hydraulic dredging operation is described on page 8 as a major constraint for a dredging remedy. However, even if such constraints were imposed to some degree, several dredging and transport approaches are available which would greatly limit the need for water treatment. These options include: (1) mechanical removal, with barge transport to shore, passive drainage, and truck to disposal/treatment; and (2) mechanical removal, with hydraulic reslurry (either at the dredging site or at onshore facilities), hydraulic transport to disposal/treatment, with recirculation of carrier water (this requires dual pipelines). There could be other possible options. Such approaches may be somewhat more expensive than conventional hydraulic dredging with direct pipeline transport, but the cost savings over water treatment may be significant and technical constraints regarding assimilative capacity would be overcome.

**Page 10 – Assumed Duration of Dredging:** Figure 19 is dramatic, however, it is based on many assumptions. For example, the stated time of 60 years to complete a dredging remedy is, in my opinion, an unreasonable assumption. The length of time for dredging, as portrayed on this figure, is based on assumptions regarding the need for water treatment and the assimilative capacity of the River. But for a major remedial project such as this, the agencies would be strongly motivated to consider a less restrictive requirement or an outright waiver of such constraints. The net benefits of a remedy would be weighed against the short-term impacts of necessary discharges of treated water.

## Capping

**Page 9:** The statement is made that the areas with highest concentration would be capped first. This approach may not be advisable for the Operable Units (OUs) 1, 3, and 4 reaches since areas capped early would be susceptible to sediment transport from uncapped upstream areas, resulting in potential re-contamination. Once sources are controlled, it is usually best to sequence the remedy actions from upstream to downstream for a riverine site. The capping of higher concentration areas first may be a more viable approach for the lower portion of OU 4 since it is subject to seiche.

**Page 9:** The statement is made that TSCA-level sediments would be capped. While I agree that a cap could likely be designed to be protective of such sediments, technical considerations are not the only considerations. A capping remedy may not meet the regulatory requirements of TSCA. I understand that EPA Region 5 has taken the position that capping TSCA sediments would not be acceptable.

**Page 13:** The concept of a Long-Term Stewardship Plan is a sound idea. Such a plan would tend to diffuse the common objections to capping remedies regarding the need for protection in perpetuity. However, the viability of the plan would depend on many details yet to be described. For example: how would the financial aspects be handled, would dams be maintained under the plan, how would potential dam removals be handled, would any needed institutional controls be enforced under the plan, etc.?

**Page 45 – Areas for Active Remediation:** Table 5 shows the acreages by reach for the areas proposed for capping. These areas presumably correspond to those shown on Figures 7 through 9. Although the Panel Report acknowledges that WDNR has selected 1 ppm as the action level (see page 67), the areas proposed for capping on Figures 7 through 9 appear to correspond to a surficial concentration of 5 ppm. It is unclear if the comparisons of dredging versus capping in the Panel Report consider this basic difference in areas for active remediation. For example, did the projections of dredging times as described in the Panel Report assume that dredging would occur in areas of 1 ppm, while capping would occur for 5 ppm areas?

**Page 47:** The statement that remediation should proceed only as long as it is continuing to reduce the SWAC is not consistent with the concept of an action level nor with an objective of mass removal, which would address future risks to exposure of now-buried high-PCB sediments. Note that the concept of a SWAC is a metric to measure the success of a remedy once it is completed. Also, the premise of continuing active remediation only as long as reductions in SWAC are apparent relies on natural attenuation to bring concentrations below the cleanup levels. The rates at which this would occur as projected in the Panel Report rely on model projects by Limno-Tech. However, I understand that recent data collected for OU 1 indicate that natural attenuation may not be occurring at the rates suggested in the Panel Report.

## Cap Designs

**Proposed Cap Design:** The rationale on the proposed cap designs is scattered between several sections in the Panel Report and is therefore somewhat difficult to follow. And there is no clear discussion of the overall rationale in selecting proposed cap thicknesses and material properties. I have tried to compare the information presented in the Panel Report with the EPA *In-Situ* Cap (ISC) guidance (Palermo et al., 1998a).

**Page 64 – Total Cap Thickness of 12 inches:** Section 5.1.1 is titled Bioturbation, but bioturbation is only one process mentioned here. The depth of bioturbation in freshwater systems is usually limited to a few inches, plus any caps on the Fox River would be designed for erosion resistance (likely armored), so bioturbation is not the overriding process. This section actually presents the Panel Report's rationale for selecting 12 inches as "a basic cap thickness." But the basis for that selection is technically inappropriate. The Panel Report references EPA (1994) (the EPA *Assessment and Remediation of Contaminated Sediments [ARCS] Remediation Guidance* document, page 53) as a justification for a 12-inch cap thickness for chemical isolation. However, chemical isolation is only one of several processes that should be considered in cap design. Further, the basis in EPA (1994) for a 12-inch minimum cap thickness for chemical isolation is based on an early study by Sturgis and Gunnison (1988), but this study is not applicable for evaluation of long-term chemical migration of contaminants due to diffusion (see Palermo et al., 1998, page 37, for more details on this). Note that Palermo et al. (1998) effectively supersedes the EPA (1994) document with respect to cap design.

The total thickness of a cap, and the composition of the cap components, should be based on an evaluation of all the pertinent processes for the Site and the ability of the design to achieve the intended functions of the cap. Some of the processes for design of cap components can be evaluated rigorously with models, etc. But others require engineering judgment. Cap design is evolving as we gain more experience across the range of project conditions. For cap design, the conservative "layer cake approach" has usually been taken (i.e., we have not assumed dual functions for the same cap component). The argument could be made that, for an armored cap, the erosion protection layer may also act effectively as the bioturbation component. But, in my judgment, a total cap thickness of 12 inches seems non-conservative for a major site like the Lower Fox River.

**Figures 7 through 9 – Cap Design for Specific Areas:** The proposed design varies considerably by area capped as shown on Figures 7 through 9. The specification of a specific design by reach or area is a viable approach, but there is no rationale presented for the specific area designs in these figures. Appendix A of the Panel Report presents a tabulation of gravel/sand particle sizes needed for resistance to erosion, and these sizes correspond to the surface layer by area as shown on the figures. However, there is no explanation or rationale for the overall designs by area presented on the figures.

A major common thread for all the area-specific designs is a 12-inch total thickness (see comment above). Another common thread for most of the designs is a 3-inch fine sand layer, which is presumably intended to be the chemical isolation layer. However, several of the areas show a design of only 12 inches of coarse sand. A coarse sand would normally have little or no fine fraction, therefore little or no adsorptive capacity for chemical isolation. If an additive such as activated carbon were used to boost adsorptive capacity, there would be a high potential for separation from a coarse sand during placement. The design for these areas therefore seems non-protective from the standpoint of chemical isolation.

**Page 33:** The Panel Report states here that a cap thickness of 2 to 6 inches is needed for physical isolation from benthos. The Panel Report further states that 6 to12 inches is a typical minimum cap thickness to "provide a safety factor, ensure cap layer remains stable even if there is significant heterogeneity in placement thickness, and to protect the overlying water from migration of contaminants through the cap." These statements essentially propose that a thin cap is a common design approach. However, most *in-situ* remediation caps which have been designed are greater in thickness than the 6 to 12 inches mentioned here.

**Page 33 – Operational Cap Thickness Component:** The Panel Report mentions unevenness of cap thickness as a consideration for cap design. But the potential for mixing of cap material with the contaminated sediments is an additional process not considered in the Panel Report. The degree of mixing is dependent on the method and rate of placement of the cap material as well as the physical/engineering properties of the cap material and contaminated sediments. The degree of mixing based on past experience has usually been on the order of a few inches. The potential for mixing should be considered in selecting an appropriate operational cap thickness component as well as in evaluations of cap effectiveness for long-term chemical isolation.

**Page 64, Section 5.1.2 – Cap Design for Chemical Isolation:** This section describes use of the contaminant flux model provided in the EPA ISC guidance document. The bottom-line results regarding flux reductions are presented, but no details are provided on the various model parameters used. What was the assumed total organic carbon (TOC) content and porosity of the cap isolation layer? Were evaluations performed for an average scenario for PCB concentrations and sediment physical properties for all reaches, or a worst-case scenario? The answers to such questions should be provided at least in summary form. The report states that model results showed a 500-fold reduction in flux to the overlying water for a 6-inch cap with 2-inch effective cap thickness. Presumably, these results were factored into the designs shown on Figures 7 through 9, but no information on this is presented.

Although reduction in flux is an important consideration, the cap design should be based on evaluations of the maximum long-term PCB concentration in the upper portion of the cap. Such evaluations would determine if the post-capping SWACs remain below the target levels, essentially in perpetuity, for a given cap design. All pertinent processes to include consolidation-induced advection and cap/sediment mixing should be considered in the evaluations. A combination of the United States Army Corps of Engineers (USACE) PSDDF and RECOVERY models have been used for such evaluations and should be considered for this Site.

**Page 65:** The report states that there is no indication of potential seepage (advection) due to groundwater flow, and so this was not considered in the model runs. However, the process of consolidation-induced advection will occur, and should be considered in the cap design.

**Page 73 – Shear Stress and Armor Design:** Statement is made here and on page 77 that the calculated particle sizes for the cap surface layer were multiplied by a 3.0 safety factor, but these statements are in conflict with that on page 75 that the shear stress for the 100-year flood was multiplied by a 3.0 factor. Page A-1 of the report states that the safety factor was applied to the shear stress, so statements on pages 73 and 77 should be corrected.

**Page 76 – Ice Scour and Shallow Water Constraints:** Statement is made that spring ice flows could gouge sediment in shallow areas, but that little of the proposed cap area is along the shallow bank areas, so the cap would not be compromised. This statement does not adequately consider what are likely significant technical constraints on application of capping in shallow water areas. WDNR has indicated that ice scour could be a constraint on cap placement in water depths of 3 feet or less. In addition, the habitat conditions to discourage carp indicate that a minimum water depth of 3 feet should be maintained. Long-term lake level changes (from +5 to -1 feet) should be accounted for in designing for these restrictions for OU 4. Therefore, no cap should be constructed within OUs 1 and 3 with a surface above -3 feet chart datum, and no cap should be constructed within OU 4 with a surface above -4 feet chart datum. Assuming that a 1-foot-thick cap, as proposed in the report, would be the final design (note that final design could result in a greater thickness), no area with a bottom elevation less than -5 feet chart datum could be capped without prior dredging to meet these depth constraints. The areas shown for cap placement on Figures 7 through 9 show what appears to be substantial areas proposed for capping near and all the way to the shoreline, indicating significant overlap with the -5-foot datum. Significant dredging would therefore be required prior to placing even a 1-foot cap in shallow water areas. All the time projections, reductions in SWAC, etc., described in the report, do not consider these constraints related to shallow water areas.

**Appendix A-1:** This appendix presents more detail on the proposed armor layer gravel sizes. Maps are presented showing distributions of shear stress for the 100-year flood event. The graphical presentation of shear stress in map format is a useful tool to visualize how the variation in armor layer design can be incorporated into a cap design.

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**TECHNICAL QUALIFICATIONS AND CONTRIBUTIONS OF ENGINEERING AND SCIENTIFIC PERSONNEL**

**Updated September 2001**

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Soil-Structure Interaction - 1974
Environmental Engineering and Ecology - 1975
Management Seminar in Value Engineering - 1975
Supervision and Group Performance - 1977
Sanitary Engineering Seminar - 1977
Water Quality Management - 1978
Dredging Technology Symposium - 1980
Dredging Engineering Symposium - 1981
Instructor Training Course, Ft. Belvoir, VA - 1981
Dredging Engineering Shortcourse - 1982
Seminar Consolidation of Fine-Grained Waste Materials - 1982
Seminar for ASCE Specialty Conference Chairmen - 1983
Dredging Technology Symposium - 1985
Nuclear Radiation Safety Shortcourse - 1989

**2. Government Service:**

A. Service Computation Date: 27 October 1967

B. Began Working at WES: 15 December 1974

C. Date Promoted to Present Grade: 1 January 1995

**3. Professional Registration:**

Registered Professional Engineer
State of Mississippi, 1975 to present, #6624

**4. Professional or Technical Societies/ Organizations and interactions with academia:**

**A. Professional or Technical Societies/ Organizations:**

1. Current membership:
International Navigation Association (PIANC)
Western Dredging Association (WEDA)

Inactive membership:
American Society of Civil Engineers (ASCE)
Society of American Military Engineers (SAME)
Society of Wetland Scientists
Vicksburg Engineers Club
Chi Epsilon (Honorary Civil Engineering Fraternity)

2. Election or appointment as an officer:

Vice-President, Vicksburg Chapter, SAME, 1980

3. Membership on committees or panels:

Program Committee Chairman, Mississippi Section ASCE, 1980
Session Chairman, ASCE Water Forum 81 Specialty Conference, 1981

Steering Committee, ASCE Dredging 84 Specialty Conference, 1983
Session Chairman, ASCE Dredging 84 Specialty Conference, 1984
Subcommittee Chairman, Marine Transportation and the Environment,
Transportation Research Board, 1991 to 1995
Associate Editor, Journal of Dredging, Western Dredging Association, 1998

4. Attendance at national and international meetings of non-governmental societies and organizations or serving as an instructor for non-government training courses:

National/ International meetings:

ASCE Specialty Conference on Dredging and Its Environmental Effects, Mobile, AL, 1976
ASCE National Environmental Engineering Conference, Nashville, TN, 1977
Ninth World Dredging Congress, Vancouver, BC, Canada, 1980
ASCE Water Forum 81 Specialty Conference, San Francisco, CA, 1981
Delegate to 7th US/Japan Experts Meeting on Management of Bottom Sediments Containing Toxic Substances, New York, NY, 1981
ASCE Dredging 84 Specialty Conference, Clearwater, FL, 1984
US-Netherlands Meeting on Dredging and Related Technology, Charleston, SC, 1984
International Joint Commission on the Great Lakes, Forum on Confined Dredged Material Disposal Facilities, Toronto, Canada, 1985
Eleventh World Dredging Congress, Brighton, United Kingdom, 1986
Eighth Annual Meeting of the Western Dredging Association, Baltimore, MD, 1986
Tenth Annual Meeting of the Western Dredging Association, Metarie, LA, 1988
Participant and Rapporteur at Marine Board, National Research Council Symposium on Contaminated Marine Sediments, Tampa, FL, 1988
Twelfth World Dredging Congress, Orlando, Florida, 1989
ASCE Ports 89 Specialty Conference, Boston, MA, 1989
Delegate to 14th U.S./Japan Experts Meeting on Management of Bottom Sediments Containing Toxic Substances, Yokohama, Japan, 1990
Participant Transportation Research Board National Meeting, 1991
Twelfth Annual Meeting, Western Dredging Assn, Las Vegas, NV, 1991
Thirteenth Annual Meeting, Western Dredging Assn, Mobile, AL, 1992
Society of Wetland Scientists, Annual Meeting, New Orleans, LA, 1992
ASCE Water Forum 92, Balitmore, MD, 1992
International Environmental Dredging Symposium, Buffalo, NY, 1992
14th Annual Meeting, Western Dredging Association, Atlantic City, NJ, 1993
15th Annual Meeting Western Dredging Association, San Diego CA, 1994
ASTM Symposium Remediation of Contaminated Sediments, Montreal Canada, 1994
16$^{th}$ Annual Meeting Western Dredging Association, New Orleans, 1996
14$^{th}$ World Dredging Congress, Amsterdam, The Netherlands, 1995
PIANC Working Group PEC-1, Open Water Disposal Management, 1996-1998
17$^{th}$ Annual Meeting Western Dredging Association, Charleston, 1997
EPA National Conference on Contaminated Sediments Management and Treatment, 1997
International Workshop on Beneficial Uses of Dredged Material, Baltimore, 1997
International Conference on Contaminated Sediments, Rotterdam, 1997
Delegate US Japan Meeting on Management of Bottom Sediments Containing Toxic Substances, Kobe, Japan 1998
15$^{th}$ World Dredging Congress, Las Vegas, 1998
PIANC Working Group PEC 5, Confined Disposal of Dredged Material, 1998 to present
International Workshop on Remediation of Marine Sediments, Sandefjord, Norway, 2000, 2001

Instructor for non-government training courses:

Lecturer at Dredging Engineering Shortcourse, Texas A&M University, annual basis
Lecturer at International Program for Port Planning and Management, Louisiana State University and University of New Orleans, annual basis
Lecturer at Coastal Engineering for the Great Lakes Shortcourse, Univ of Wisconsin, 1991
Lecturer at Contaminated Sediment Remediation Shortcourse, Univ of Wisconsin, annual basis

**B. Interactions with academia:**

1. Rank/ Position

Adjunct Faculty Member, Hinds Community College
Adjunct Professor, Mississippi State University
Visiting Assistant Professor, Texas A&M University

2. Classes taught:

Undergraduate:
Hinds Community College,
TCE 1111, Intro to Civil Engineering Technology
TCE 2183, Intro to Environmental Engineering Technology

Graduate:
Mississippi State University,
CE 8913, Dredging and Dredged Material Disposal, 1987
CE 8803, Intro to Environmental Engineering I, 1991
Texas A&M University,
OCEN 688, Marine Dredging, 1990, 1993, 1995

3. Service on PhD/MS Committees

Texas A&M University
Clifford L. Truitt, Doctor of Engineering, Ocean Engineering, 1987
Anthony J. Risko, MS Ocean Engineering, 1994
Gregory L. Williams, PhD Ocean Engineering, 1996-2001

4. Service on PhD Qualifying Committees

5. Service on Academic Boards

Member and Co-Chairman of the Advisory Committee, Hinds Community College, Engineering Technology Program, 1982 to 1994
Advisory Board for Coastal Engineering Education Program, Texas A&M University

**5. Participation in committees, panels, meetings, conferences, or symposia:**

**A. Attendance at Government sponsored national meetings and/or membership on Government sponsored technical committees, panels, and instructor for government sponsored training, etc:**

Committees/ panels:

Program Planning Group for the Environmental Effects of Dredging Programs, 1982 to present
WES Study Team for Planning the Environmental and Water Quality Operational Studies (EWQOS) Program, 1976
Program Control Group for the EWQOS Program, 1977-1979
Coordinator and Chairman for Confined Dredged Material Disposal Workshop, 1981
Review Committee for the Corps of Engineers National Waterways Study, 1980-1981
Corps of Engineers Environmental Advisory Board Meeting, 1983
Corps of Engineers-EPA Technical Working Group on RCRA and Dredged Material, 1985
Corps of Engineers-EPA Oakland Harbor Review Panel, 1988
National Workshop on Dredging Impacts on Sea Turtles, 1988
Value Engineering Study Panel, Marathon Battery Superfund Project, 1988
Workgroup Leader for National Corps Workshop on Wetlands, 1989
Corps of Engineers Contaminated Sediments Workshop, 1989
Washington Department of Ecology Workshop on Development of Confined Dredged Material Disposal Standards, 1989
Corps/American Association of Port Authorities Workshop on Long Term Management Strategies for Dredged Material Disposal, 1989
Value Engineering Study Panel, Bayou Bonfouca Superfund Project, 1990
Corps/EPA National Ocean Disposal Coordinators Meeting, 1990.
American Association of Port Authorities Seminar on Dredged Material, 1990
USACE Water Quality Seminar, 1990
San Diego Bay Symposium, 1990
EPA/USACE Workgroup, Dredged Material Ocean Testing Manual, 1991-1993
National Symposium for Long Term Management Strategies, 1991
EPA/USACE National Ocean Disposal Coordinators Meeting, 1991
NOAA National Workshop on Contaminated Sediment Remediation, 1991
USACE/EPA Workgroup on Technical Framework for Dredged Material Disposal Alternatives, 1991-1992
EPA/USACE Workgroup, Dredged Material Inland Testing Manual, 1991-1993
National Zebra Mussel Control Workshop, Nashville, TN 1992
EPA/USACE National Ocean Disposal Coordinators Meeting, 1993
Coastal Engineering Research Board Meeting, Mobile Al, 1993
Coordinator for National Wetlands Engineering Workshop, St. Louis MO, 1993
Flemish Government Contaminated Sediments Workshop, Gent Belgium, 1994
Dredged Material Beneficial Uses Workshop, Philadelphia, PA, 1994
Interagency Review Team, Manistique Harbor Superfund Site, 1994
Cooperative Research and Development Agreement with ERM Hong Kong Inc. 1996
EPA Contaminated Aquatic Sediments Remedial Guidance Workgroup, 1997 to present
Ross Island Interagency Technical Advisory Committee, State of Oregon, 1998 to present
Housatonic Superfund Technical Advisory Board, Region 1 EPA, 1998 to present
EPA Remediation Techologies Development Forum, 1998 to present
EPA Forum on Managing Contaminated Sediments at Hazardous Waste Sites, 2001

Instructor for government sponsored training courses:

Instructor in Soils and Geology, U.S. Army Engineer School, Ft. Belvoir, VA, 1981 to 1984
Lecturer at Corps of Engineers PROSPECT courses on Dredged Material Management, Deep Draft Navigation, and Tidal Hydraulics, as needed basis
Lecturer at EPA/USACE Dredged Material Management Seminars, annual basis

**B. Membership on Government committees:**

USACE Committee on Tidal Hydraulics, 1995 to present
Non Technical:
Chairman of WES Automated Products Advocates Team 1991-1992.
Chairman Technical Evaluation Committee for Task Order Contract on Environmental Engineering for Dredged Material Disposal 1992.
AE Selection Board for WES Engineering and Construction Services Division 1992.

**6. Honorary, scientific or engineering societies:**

Beta Chi Epsilon (Honorary Civil Engineering Fraternity), Mississippi State University, 1970
Chi Epsilon (Honorary Civil Engineering Fraternity), Mississippi State University, 1971

**7. Special recognition or awards:**

Director's Award, EPA Office of Emergency and Remedial Response for work on Manistique Harbor Superfund Interagency Review Team, 1996.

Commander and Director's Research and Development Achievement Award, 1990

Special Commendation for Exemplary Performance, 1973 Flood Fighting Operations, Chief of Engineers, 1973

Adopted Suggestion, 1974

Sustained Superior Performance Awards: 1976, 1980

Significant Accomplishment Awards: 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989

Quality Step Increases: 1993, 1994

Letters of Commendation:

District Engineer, Vicksburg District, 1970
District Engineer, Vicksburg District, 1971
Division Engineer, Lower Mississippi Valley Division, 1974
Director, Waterways Experiment Station, 1975
Commander and Director, Waterways Experiment Station, 1978
District Engineer, Norfolk District, 1981
District Engineer, Savannah District, 1982
Executive Director, Society of American Military Engineers, 1983
Chief of Engineers, 1983
Maryland Environmental Service, 1984

Chief, Dredging Division, Water Resources Support Center, 1985
Chief, WES Environmental Laboratory, 1985
District Engineer, Seattle District, 1985
Director, Water Resources Support Center, 1986
District Engineer, Seattle District, 1986
Division Engineer, North Pacific Division, 1986
Division Engineer, North Pacific Division, 1987
District Engineer, San Francisco District, 1988
Sacramento District, 1988
National Research Council, 1988
Chief, WES Hydraulics Laboratory, 1990
Environmental Protection Agency, Region I, 1990
HQ US Army Corps of Engineers, 1990
HQ Environmental Protection Agency, 1990
HQ US Army Corps of Engineers, 1991
HQ US Army Corps of Engineers, 1992
HQ US Army Corps of Engineers, 1993
Asst Director, R&D, HQ US Army Corps of Engineers, 1993
Executive Secretary, Coastal Engineering Research Board, 1993
EPA Office of Emergency and Remedial Response, 1996
Black and Veatch, 1996
District Engineer, Norfolk, 1996
Director of Civil Works, 1998
USACE Project Delivery Team Excellence Award, 2001.

**8. New designs, techniques, inventions, or patents etc. that advance the state of the art in areas of specialization:**

Developed techniques for restoration of capacity of dredged material disposal sites through beneficial uses of dredged material.

Developed engineering design guidelines for marsh creation using dredged material.

Developed concepts and approaches for management of confined dredged material disposal sites to increase capacity by dewatering and consolidation.

Developed technique and laboratory test protocol for predicting the chemical quality of effluent discharged from confined dredged material disposal areas.

Developed techniques for design of dredged material disposal areas for solids retention and initial storage.

Responsible for developing comprehensive engineering design guidance for dredging and dredged material disposal in the Corps Engineer Manual 1110-2-5020 series.

Principal on team that developed the Corps Management Strategy and Decision Making Framework for disposal of contaminated sediments.

Principal on team that developed technical guidance for implementation of Corps regulatory programs for dredged material disposal (ocean and U.S. waters).

Developed USACE technical guidance for subaqueous capping of contaminated dredged material.

Developed engineering design sequence for wetland enhancement and restoration projects.

Developed EPA technical guidance for in-situ capping of contaminated sediments.

**9. Known projects/investigations, etc. that other researchers are conducting that are the result of my work:**

Use of elutriate test procedures for prediction of contaminant release due to dredgehead operation.

Development of expert systems for dredging design applications under the Automated Dredging and Disposal Alternatives Management System (ADDAMS).

Development of comprehensive management and decisionmaking strategies for dredging and disposal of contaminated and non-contaminated sediments.

Development of wetland engineering guidance for substrate development, hydrology and vegetation establishment and computer-assisted procedures for wetland restoration projects.

**10. Narrative description of significant examples of team work.**

**A. Within the laboratory community.**

1974-1982. WES team leader for development of techniques for evaluation of dredged material consolidation and dewatering processes. These efforts involved coordination and technical supervision of teams from WES Geotechnical Laboratory and Environmental Laboratory.

1983-1986. Provided technical supervision for research and field studies on sediment resuspension characteristics of dredges. This study involved field monitoring teams from the WES Hydraulics and Environmental Laboratories.

1985-1986. Co-developer of Management Strategy for Disposal of Dredged Material. Technical team was composed of representatives for all Environmental Laboratory Divisions.

1985-1987. WES PI and study manager for Everett Homeport project for U.S. Navy, involving evaluation of open water capping and confined disposal alternatives for contaminated sediments. Study team composed of representatives from Environmental, Hydraulics, and Geotechnical Laboratories.

1986 to 1994. WES PI for subaqueous capping task area of the Dredging Research Program. This effort was managed by the Coastal Engineering Research Center and involved cooperative work with CERC researchers.

1990-1992. WES PI for Long Term Management Strategy for US Navy in lower Chesapeake Bay. Study involved EL and CERC researchers.

1991 to 1994. Acting as WES PI for Wetlands Engineering work unit of the WRP, providing technical supervision of research tasks performed by HL, GL, and EL researchers.

1992 to 1995. WES PI and Study Manager for Montrose Sediment Remediation project. Providing technical coordination and supervision of a team of over 15 WES engineers and scientists from EL, HL, CERC, and GL.

1994 to present. WES PI and Study Manager for Montrose In-Situ Capping studies in support of EPA Superfund program. Providing technical coordination and supervision of a team from EL, CHL, and GL.

1995 to 1999. WES Technical Team Leader for studies in support of the Dredged Material Management Plan for the Port of New York and New Jersey. Providing technical coordination and supervision of a research team from EL, CHL, and GL.

1997 to present. Focus Area Manager for Contaminated Sediments research under the Dredging Operations and Environmental Resarch (DOER) program.

1997. Study team member for USACE R&D Return on Investments (ROI) study, with team members from WES, Construction Engineering Research Laboratory, Cold Regions Research and Engineering Laboratory, and Topgraphic Engineering Center.

**B. Outside the laboratory community**

1991-1992. Chairman for EPA/USACE workgroup on development of the Technical Framework for Environmental Evaluation of Dredged Material Management Alternatives. This workgroup was composed of representatives of several EPA HQ offices, EPA Regions, USACE HQ, and USACE Divisions and Districts.

1994 to 1997. WES PI for EPA research on guidelines for in-situ capping as a remediation technique for contaminated sediments. Providing technical coordination and supervision of a research team from Lousiana State University and WES.

1997-1998. Member of Permanent International Association of Navigation Congresses, Permanent Environmental Committee Working Group PEC1, responsible for development of international guidelines for management of open water placement of dredged material.

1998. Manager for study of disposal alternatives development for Multiple User Disposal Site (MUDS) study funded by the State of Washington through the USACE Seattle District, involving efforts by Washington Dept of Ecology, private consultants, and Washington Ports Association.

Current. Member of Permanent International Association of Navigation Congresses, Permanent Environmental Committee Working Group PEC5, responsible for development of international guidelines for confined (diked) dredged material disposal.

Current. Chairman of EPA Contaminated Aquatic Sediments Remedial Guidance Workgroup, Subaqueous Capping Subgroup, responsible for development of implementing guidance for Superfund remedial project managers.

**11. Professional Publications:**

A. Refereed journal/textbook publications: 22
B. Proceedings of conferences and symposia:
(1) Refereed: 31
(2) Others: 32
C. All other professional publications:
(1) WES/ ERDC publications: 65
(2) Others: 25

Total publications: 175

**A. Refereed publications in journals of professional societies, textbook chapters, etc:**

Miller, J.L., Palermo, M.R., and Groff, T.W. 2001. "Hopper Overflow Characteristics for the Delaware River," Journal of Dredging Engineering, Western Dredging Association, Vol 3, No. 1, March 2001.

Olin-Estes, T.J. and Palermo, MR. 2001. "Recovery Of Dredged Material For Beneficial Use: The Future Role Of Physical Separation Processes," Journal of Hazardous Materials, 85 (2001) pp39-5, Elsevier.

Palermo, M.R. 2000. "Disposal and Placement of Dredged Material," In Herbich, J.B. (editor). *Handbook of Coastal Engineering*. McGraw Hill. New York, N.Y. ISBN 0-07-134402-0.

Palermo, M.R. 2000. "Subaqueous Capping of Contaminated Sediment," In Herbich, J.B. (editor). *Handbook of Coastal Engineering*. McGraw Hill. New York, N.Y. ISBN 0-07-134402-0.

Palermo, M.R. 1998. "Design Considerations for *In-Situ* Capping of Contaminated Sediments," Water Science and Technology, Vol. 37, No. 6-7, pp. 315-321.

Ling, H.I., Leshchinsky, D., Gilbert, P.A., and Palermo, M.R. 1996. "In-Situ Capping of Contaminated Submarine Sediments: Geotechnical Considerations," Proceedings of the Second International Congress of Environmental Geotechnics, IS-Osaka '96, Osaka, Japan, published in Environmental Geotechnics, edited by Masashi Kamon, A.A. , 1996, Balkem, Rotterdam, The Netherlands, pp 575-580.

Palermo, M.R. and Clausner, J.N. 1996. "Concepts for Sediment Remediation on the Palos Verdes Shelf, California," Remediation- The Journal of Environmental Cleanup Costs, Technologies, and Techniques, Vol. 6, No. 4, Autumn 1996, John Wiley and Sons, Inc.

Palermo, M.R. and Miller, J.A. 1995. "Strategies for Management of Contaminated Sediments," in Dredging, Remediation, and Containment of Contaminated Sediments", edited by Demars, K.R., Richardson, G.N., Yong, R.N. and Chaney, R.C., American Society of Testing and Materials (ASTM) Special Technical Publication 1293, ASTM, Philadelphia, PA.

Palermo, M.R. 1994. "Technical Framework for Environmental Evaluation of Dredged Material Management Alternatives," World Dredging and Marine Construction, January 1994.

Palermo, M.R., Engler, R.M. and Francingues, N.R. 1993. "The U.S. Army Corps of Engineers Perspective on Environmental Dredging," Buffalo Environmental Law Journal, Vol. 1, Fall 1993, No. 2., Buffalo, N.Y.

Thackston, E.L. and Palermo, M.R. 1992. "Predicting Effluent PCB's from Superfund Site Dredged Material," Journal of Environmental Engineering, American Society of Civil Engineers, Vol. 118, No. 5, September/October, 1992.

Palermo, M.R. 1992. "Long Term Storage Capacity of Confined Disposal Facilities," Chapter 8, Handbook of Dredging Engineering, McGraw Hill.

Palermo, M.R. and Hayes, D.F. 1992. "Environmental Effects of Dredging," Vol. 3, Chapter 15 of Handbook of Coastal and Ocean Engineering, Gulf Publishing Company, Houston, Texas.

Palermo, M.R. 1992. "Dredged Material Disposal," Vol. 3, Chapter 6 of Handbook of Coastal and Ocean Engineering, Gulf Publishing Company, Houston, Texas.

Engler, R.M., Francingues, N.R., and Palermo, M.R. 1991. "Managing Contaminated Sediments: Corps of Engineers Posturing to Meet the Challenge," World Dredging and Marine Construction, August 1991.

Palermo, M.R. 1991. "Equipment Choices for Dredging Contaminated Sediments," Remediation - The Journal of Environmental Cleanup Costs, Technologies, and Techniques, Executive Enterprises Co. Inc., New York, NY, Autumn 1991.

Palermo, M.R. 1989. "Corps of Engineers Manual Series on Dredging and Dredged Material Disposal," World Dredging and Marine Construction, July/August 1989.

Palermo, M.R. and Thackston, E.L. 1988. "Verification of Predictions of Dredged Material Effluent Quality," Journal of Environmental Engineering, American Society of Civil Engineers, Vol 114, No. 6, December 1988.

Palermo, M.R. and Thackston, E.L. 1988. "Test for Dredged Material Effluent Quality," Journal of Environmental Engineering, American Society of Civil Engineers, Vol 114, No. 6, December 1988.

Palermo, M.R. and Thackston, E.L. 1988. "Flocculent Settling Above the Zone Settling Interface," Journal of Environmental Engineering, American Society of Civil Engineers, Vol 114, No. 4, August 1988.

Palermo, M.R. 1984. "Technique Developed for Prediction of Effluent Quality for Confined Disposal Areas," World Dredging and Marine Construction, May 1984.

Palermo, M. R., Montgomery, R. L., and Raymond, G. L. 1983. "Techniques for Reducing Contaminant Release During Dredging Operations," Proceedings, Integration of Ecological Aspects in Coastal Engineering Projects, Rotterdam, the Netherlands.

**B. Publications in proceedings of professional conferences and/or symposia:**

**(1) Refereed conference/ proceedings papers:**

Palermo, M.R. and J.R. Wilson. 2000. "Corps of Engineers Role In Contaminated Sediment Management And Remediation," Proceedings, American Bar Association, Section of Environment, Energy, and Resources, Panel on Contaminated Sediments: Science, Law, and Politics, 8$^{th}$ Section Fall Meeting, 22 September, 2000, New Orleans, Louisiana.

Palermo, M.R., Ebersole, B. and Peyman-Dove, L. 1998. “Siting of Island CDF and CAD Pit Options For The Port of New York/ New Jersey” , Proceedings, Fifteenth World Dredging Congress, Las Vegas, NV, June 28-July 2, 1998.

Thackson, E.L, and Palermo, M.R. 1998. “Improved Methods for Correlating Turbidity and Suspended Solids for Dredging and Disposal Monitoring” , Proceedings, Fifteenth World Dredging Congress, Las Vegas, NV, June 28-July 2, 1998.

Palermo, M.R. and Wilson, J. 1997. “Dredging State of the Practice: Corps of Engineers Perspective,” *Proceedings, Geologan 97, The First National Conference of the Geo-Institute, Logan, Utah, July 15-19, 1997*, American Society of Civil Engineers, New York, New York.

Risko, A.J., Randall, R.E., and Palermo, M.R. 1995. "Modeling Placement and Stability of Subaqueous Capped Contaminated Dredged Sediments within Santa Monica Bay, California," Proceedings of the 14th World Dredging Congress, World Organization of Dredging Associations, Amsterdam, The Netherlands, November 1995.

Landin, MC., Palermo, M.R., Patin, T.R., Clarke, D.G., and Davis, J.E. 1995. "Environmental Restoration and Habitat Development using Dredged Material in U.S. Waters," Proceedings of the 14th World Dredging Congress, World Organization of Dredging Associations, Amsterdam, The Netherlands, November 1995.

Palermo, M.R. and Vogt, C. 1995. "U.S. Guidelines for Environmental Evaluation of Dredged Material Disposal Alternatives," Proceedings of the 14th World Dredging Congress, World Organization of Dredging Associations, Amsterdam, The Netherlands, November 1995.

Loglgian, J.M., Dudek, E.A, and Palermo, M.R. 1994. "Design of Dredge Containment and Dewatering Facilities for Marathon Battery Superfund Project," Proceedings of Dredging 94, The Second International Conference and Exhibition on Dredging and Dredged Material Placement, American Society of Civil Engineers, Lake Buena Vista, FL.

Francingues, N.R. and Palermo, M.R. 1994. "Technical Guidelines for Dredged Material," Proceedings of Dredging 94, The Second International Conference and Exhibition on Dredging and Dredged Material Placement, American Society of Civil Engineers, Lake Buena Vista, FL.

Palermo, M.R., Fischenich, C.J., Dardeau, E.A., and Zappi, P. 1994. "Guidance for Wetland Restoration with Dredged Material," Proceedings of Dredging 94, The Second International Conference and Exhibition on Dredging and Dredged Material Placement, American Society of Civil Engineers, Lake Buena Vista, FL.

Palermo, M.R., 1994. "Placement Techniques for Capping Contaminated Sediments," Proceedings of Dredging 94, The Second International Conference and Exhibition on Dredging and Dredged Material Placement, American Society of Civil Engineers, Lake Buena Vista, FL.

Palermo, M.R., Engler, R.M. and Francingues, N.R. 1992. "Corps of Engineers Perspective on Environmental Dredging," Proceedings of International Symposium on Environmental Dredging, Buffalo, NY, 30 Sep-3 Oct 1992.

Hayes, D.L., and Palermo, M.R. Engineering Aspects of Wetland Design," 1992. Proceedings of the Water Resources Sessions at Water Forum 92, American Society of Civil Engineers, 2-6 August, 1992.

Palermo, M.R., Lee, C.R., and Francingues, N.R. 1989. "Management Strategies for Disposal of Contaminated Sediments," Contaminated Marine Sediments - Assessment and Remediation, Marine Board, National Research Council, National Academy Press, Washington, D.C.

Palermo, M.R. 1989. "Capping Contaminated Dredged Material in Deep Water," Proceedings of the Specialty Conference Ports 89, American Society of Civil Engineers, Boston MA.

Payonk, P.M. and Palermo, M.R. 1989. "Clamshell Dredging and Overflow Monitoring," Proceedings of the WODCON XII, Dredging: Technology, Environmental, Mining, World Dredging Congress, Orlando, FL., 2-5 May 1989.

Palermo, M.R. and Randall, R.E. 1989. "Practices and Problems Associated with Economic Loading and Overflow of Hoppers and Scows," Proceedings of the WODCON XII, Dredging: Technology, Environmental, Mining, World Dredging Congress, Orlando, FL., 2-5 May 1989.

Thackston, E.L. and Palermo, M.R. 1988. "A Procedure for Predicting Pollutant Concentrations in the Effluent from Confined Dredged Material Disposal Areas," Heavy Metals in the Hydrologic Cycle, Proceedings of the Conference on Chemicals (Heavy Metals) in the Environment, Lisbon Portugal.

Payonk, P.M., Palermo, M.R., and Teeter, Allen M. 1988. "Clamshell Dredging and Overflow Monitoring, Military Ocean Terminal, Sunny Point, N.C.," Proceedings of the Symposium on Coastal Water Resources, American Water Resources Association, Wilmington, NC, May 22-25, 1988.

Malek, J. and Palermo, M.R. "Application of a Management Strategy for Dredging and Disposal of Contaminated Sediments to Proposed U.S. Navy Homeport Project at East Waterway," Proceedings of Coastal Zone 87, Fifth Symposium on Coastal and Ocean Management, Seattle, WA., May 26-29, 1987.

Palermo, M.R., Francingues, N.R., Lee, C.R., and Peddicord, R.K. 1986. "Evaluation of Dredged Material Disposal Alternatives: Test Protocols and Contaminant Control Measures," Proceedings of the WODCON XI, World Dredging Congress, Brighton, UK.

Hummer, C.W., Greener, G.E., and Palermo, M.R. 1984. "The National Dredging Data Management System," Proceedings of the Specialty Conference Dredging 84, American Society of Civil Engineers, Clearwater, FL.

Thackston, E.L., Montgomery, R.L., and Palermo, M.R. 1984. "Settling of Dredged Material Slurries," Proceedings of the Specialty Conference Dredging 84, American Society of Civil Engineers, Clearwater, FL.

Francingues, N.R. and Palermo, M.R. 1984. "Management Strategy for the Disposal of Dredged Material," Proceedings of the Specialty Conference Dredging 84, American Society of Civil Engineers, Clearwater, FL.

Palermo, M. R. 1984. "Design of Confined Disposal Areas for Retention of Contaminants," Proceedings of the Specialty Conference Dredging 84, American Society of Civil Engineers, Clearwater, FL.

Palermo, M. R., Montgomery, R. L., and Raymond, G. L. 1983. "Techniques for Reducing Contaminant Release During Dredging Operations," Proceedings, Integration of Ecological Aspects in Coastal Engineering Projects, Rotterdam, the Netherlands.

Palermo, M. R. 1981 "A Management Plan for Craney Island Disposal Area," Proceedings of the Specialty Conference Water Forum 81, American Society of Civil Engineers, San Francisco, CA.

Patin, T. R., and Palermo, M. R. 1981. "Productive Uses of Dredged Material," Proceedings of the Specialty Conference Water Forum 81, American Society of Civil Engineers, San Francisco, CA.

Palermo, M. R. 1980. "Long Term Storage Capacity of Dredged Material Containment Areas," Proceedings of WODCON IX, World Dredging Congress, Vancouver, British Columbia, Canada.

Montgomery, R. L., and Palermo, M. R. 1976. "First Steps Toward Disposal Area Reuse," Proceedings of the Specialty Conference on Dredging and Its Environmental Effects, American Society of Civil Engineers, January 1976, Mobile, AL.

**(2) Other conference/ proceedings papers:**

Palermo, M.R., F. Schauffler, T. J. Fredette, J. Clausner, S. McDowell, and E. Nevarez. 2001. Palos Verdes Shelf Pilot Capping: Description and Rationale. Proceedings, 21st Annual Meeting of the Western Dredging Association (WEDA XXI) and 33rd Annual Texas A&M Dredging Seminar, Houston, TX.

Peddicord, R., J. Brannon, T. Bridges, J. Cura, R. Engler, C. Lee, M. Palermo, C. Price, R. Price, R. Schroeder, J. Simmers, H. Tatem, and J. Wilson. 2000. "Evaluation of Dredged Material Proposed for Placement in Upland Sites," Proceedings, Western Dredging Association 20th Technical Conference and 32nd Annual Texas A&M Dredging Seminar, June 25-28, 2000, Warwick, Rhode Island.

Palermo, M. and D. Averett. 2000. "Summary of Constructed CDF Containment Features for Contaminated Sediments," Proceedings, Western Dredging Association 20th Technical Conference and 32nd Annual Texas A&M Dredging Seminar, June 25-28, 2000, Warwick, Rhode Island.

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# WHITE PAPER NO. 6B – *IN-SITU* CAPPING AS A REMEDY COMPONENT FOR THE LOWER FOX RIVER

***Response to a Document by The Johnson Company***

**ECOSYSTEM-BASED REHABILITATION PLAN –**
**AN INTEGRATED PLAN FOR HABITAT ENHANCEMENT AND**
**EXPEDITED EXPOSURE REDUCTION IN THE**
**LOWER FOX RIVER AND GREEN BAY**

January 2002

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**December 2002**

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# ABSTRACT

This White Paper is the second in the series in which the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA), through Dr. Michael Palermo, address the capping alternative remedy proposed by the Appleton Paper, Inc. Panel's (API Panel's) report entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (referred to herein as the "Panel Report") (The Johnson Company, 2002), and the multiple comments received during the comment period on capping as a remedial alterative. While WDNR and EPA did not include *in-situ* capping (ISC) as part of the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001), they had, and continue to acknowledge that ISCs are feasible, implementable, and effective. WDNR and EPA have concluded that while capping could be considered a component of the final remedial alternative for the Lower Fox River, it cannot be the sole remedial action on the Lower Fox River, and it would not eliminate the need for removal actions in order to meet the defined goals within the Proposed Plan.

This White Paper examines ISC as a remedy for the Lower Fox River. In light of the Panel Report, it was necessary for WDNR and EPA to articulate site-specific design criteria for the Lower Fox River consistent with national guidelines, national and international experience at constructing and monitoring ISCs, and local, Wisconsin state, and federal requirements. To that end, this White Paper articulates the minimal engineering design evaluations needed including modeling to assess consolidation, the potential for advective and diffusive flux from either consolidation or from groundwater intrusion, and evaluation of local capping material and iterative design testing to ensure that cap design is effective in chemical isolation.

This White Paper elucidates the technical considerations for potential capping areas, including that the overall remedy must manage all sediments within the 1 part per million (ppm) contour, and should achieve a sediment-weighted average concentration (SWAC) of 250 parts per billion (ppb); that no capping would occur in designated navigation channels in areas of infrastructure such as pipelines, utility easements, bridge piers, etc. (with appropriate buffer) in areas with polychlorinated biphenyl (PCB) concentrations exceeding Toxic Substances Control Act (TSCA) levels, in shallow-water areas because of habitat and ice scour considerations without prior deepening to allow for cap placement.

This White Paper further sets forth key design elements for any potential capping remedy including physical isolation of the PCB-contaminated sediments from benthic organisms; physically stability from any scour event; isolation of the PCB-contaminated sediments in perpetuity from flux or resuspension into the overlying surface waters based upon a performance criteria for chemical isolation of 250 ppb of PCBs in the cap sediment in the biologically active zone. Further, the cap design will consider operational factors such as the potential for cap and sediment mixing during cap placement and variability in the placed cap thickness, and it will incorporate an appropriate factor of safety to account for

uncertainty in site conditions, sediment properties, and migration processes. Finally, institutional/regulatory constraints associated with capping, such as capping TSCA materials, lake bed grants, riparian owner issues, deed restrictions, fiduciary responsibility, and long-term liability should be fully considered in selecting potential areas for and design of any cap.

# 1 INTRODUCTION

## 1.1 BACKGROUND

Sediments in the Lower Fox River are contaminated with PCBs. Remedial alternatives for the Site are currently being evaluated by the WDNR and EPA. This White Paper describes considerations for further evaluation of an ISC as an alternative for the project.

ISC was identified within the *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002a) as an appropriate and applicable remedy for consideration within the Lower Fox River and Green Bay. Illustrative designs for ISCs were described in the FS and incorporated into alternatives evaluated for each Operable Unit (OU) of the River based upon site-specific physical considerations. *In-situ* caps were then further evaluated using the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) criteria related to short- and long-term effectiveness, implementability, reduction in toxicity, mobility, volume through treatment, and cost.

The WDNR and the EPA did not include ISCs as part of the Proposed Plan. While acknowledging that ISCs are effective, feasible, implementable, and are effective in the short-term, long-term concerns over maintenance of the current hydraulic controls (i.e., dams, water depth, and navigation channels) and costs/responsibilities associated with operations and maintenance of a cap in perpetuity were reasons cited for not including capping as part of the Proposed Plan. While capping could be considered a component of the final remedial alternative for the Lower Fox River, it cannot be the sole remedial action. Capping does not eliminate the need for removal actions in order to meet the defined goals within the Proposed Plan.

Multiple comments were received from public and private entities on capping alternatives for the Lower Fox River; both supporting and opposing any capping within the River. Opponents of capping focused on the commitments needed to maintain long-term cap integrity and provide for public safety, while cap proponents criticized the WDNR for failing to include a capping alternative in the Proposed Plan. One of the Potentially Responsible Parties (PRPs) for the Lower Fox River, Appleton Papers Inc., assembled a panel (API Panel) of university professors and researchers to evaluate the removal and capping alternatives proposed for the Lower Fox River. The API Panel critiqued the site-specific criteria articulated in the FS, and produced an alternative plan (the Panel Report) for capping major portions of the Lower Fox River (The Johnson Company, 2002).

In light of the Panel Report, it was necessary to articulate site-specific design criteria for the Lower Fox River consistent with national guidelines, national and international experience at constructing and monitoring ISCs, and local, Wisconsin state, and federal requirements.

## 1.2 PURPOSE AND SCOPE

The goal of this paper is to provide specific guidance on how a capping alternative should be designed, evaluated, and managed to include long-term requirements for monitoring and institutional controls for the Lower Fox River. It is intended to address concerns raised regarding long-term protection from contaminants, long-term liability, and operations and maintenance.

This paper describes the technical, regulatory, and institutional considerations for selecting and designing subaqueous ISC as a remedy component for the Lower Fox River. General technical considerations for ISC design are summarized and specifics on application of existing cap design guidance for the Lower Fox River are described. This White Paper follows the ISC chapter in EPA's recent release *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA, 2002). This paper also considers Wisconsin and federal laws as they may impact final selection and design of an ISC alternative.

## 1.3 CAPPING AS A REMEDIAL ALTERNATIVE

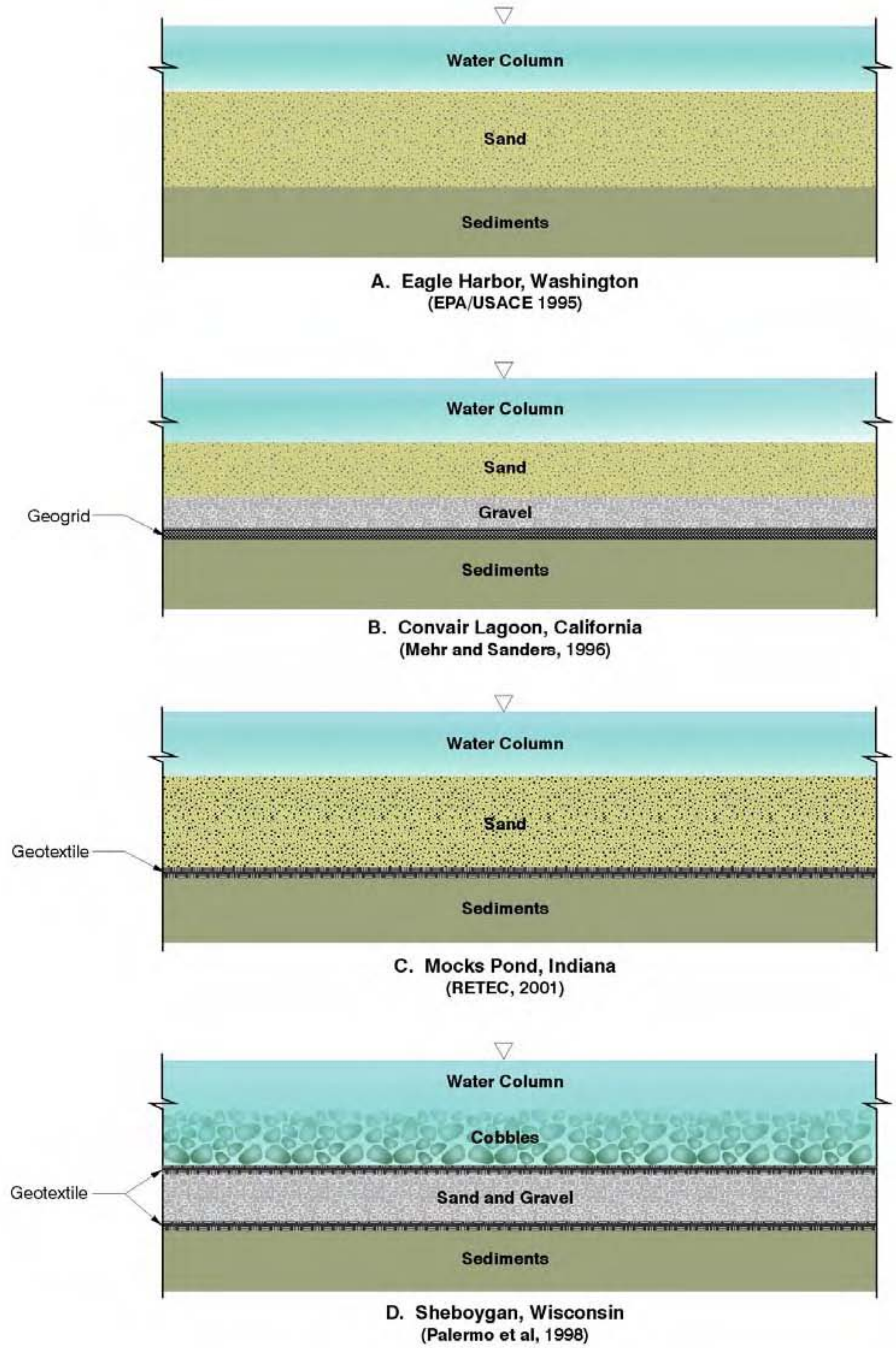
### 1.3.1 Definitions

For the purposes of evaluating capping within the Lower Fox River, the following definitions are applicable.

***In-Situ* Capping** is defined as the placement of an engineered subaqueous cover, or cap, of clean isolating material over an *in-situ* deposit of contaminated sediment. Capping of subaqueous contaminated sediments is an accepted engineering option for managing dredged materials and for *in-situ* remediation of contaminated sediments (EPA, 1994, 2002; NRC, 1997, 2001; Palermo et al., 1998a, 1998b). *In-situ* caps are generally constructed using granular material, such as clean sediment, sand, or gravel, but cap designs can include geotextiles, liners, and multiple layers. Such engineered caps are also called isolation caps. Figure 1 illustrates several example isolation cap designs. *In-situ* capping may be considered as a sole remedial alternative or may be used in combination with other remedial alternatives (e.g., removal and monitored natural recovery). For example, areas of higher contamination can be dredged and areas with a lower level of contamination can be capped.

***In-situ* Capping with Partial Removal** is an option involving placement of an ISC over contaminated sediments which remain in place upon completion of a partial dredging action. In this case, ISC involves the removal of contaminated sediment to some depth followed by ISC of the remaining sediment. This can be suitable where capping alone is not feasible due to habitat, hydraulic, navigation, or other restrictions on minimum water depth. *In-situ* capping with partial dredging can also be used when leaving deeper contaminated sediment capped in place is desirable for preserving bank or shoreline stability. When ISC is used with partial dredging, the cap is designed as an engineered isolation cap, since a portion of the contaminated sediment deposit is not dredged and remains in place.

## FIGURE 1 EXAMPLES OF CAP DESIGNS



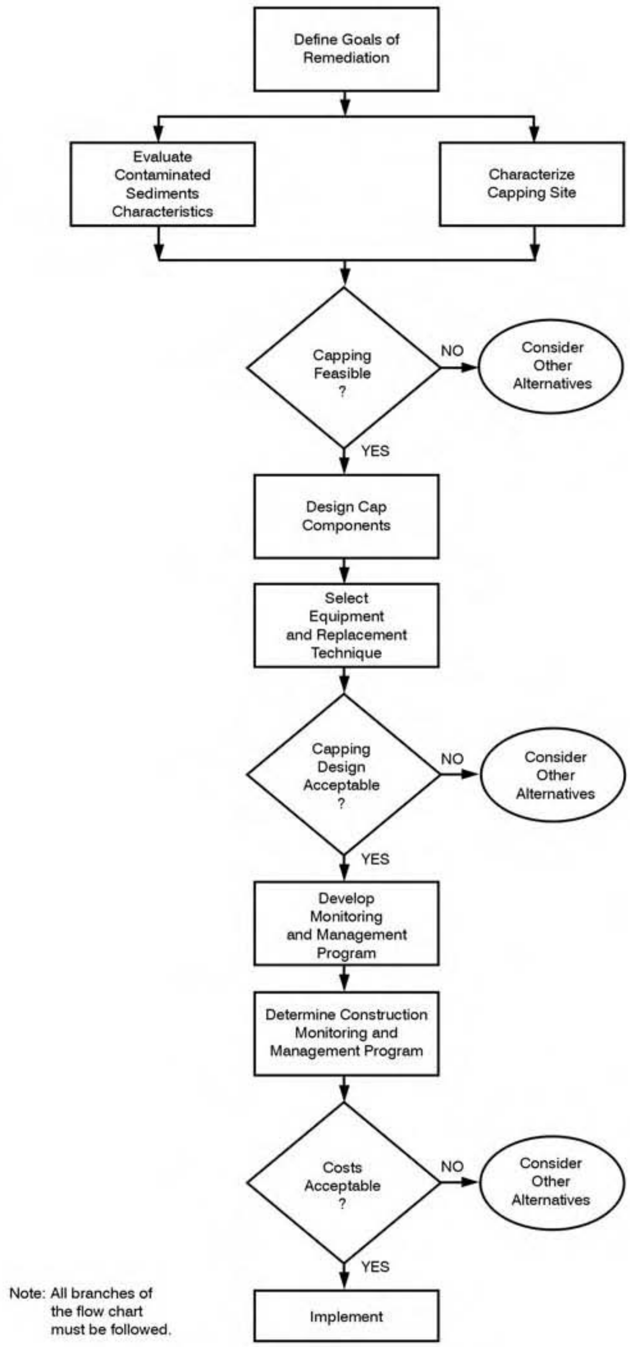
**Residual Capping** is defined as placement of a thin cap layer over a thin layer of residual sediment left behind following dredging. In this case, the dredging operation is designed to remove all the contaminated sediments, but the dredging process resuspends contaminated sediment that resettles onto the dredged surface, forming the residual layer. Such residual layers are typically a few centimeters thick. Residual capping serves to dilute this thin layer of contaminated sediment and speed up the natural recovery process. Residual caps are not designed as isolation caps. An example of a residual cap is the material placed at the Sediment Management Unit (SMU) 56/57 demonstration project.

Residual capping may be employed in OUs of the Lower Fox River as a means to manage residual sediments following completion of removal. *In-situ* capping (isolation capping) may be employed as a remedy component in areas not dredged, or in areas with minimal removal. This paper focuses primarily on considerations for isolation capping as a remedy component.

### 1.3.2 Capping Guidance Documents

Detailed guidance for subaqueous dredged material capping and ISC for sediment remediation has been developed by the U.S. Army Corps of Engineers (USACE) and EPA. The documents *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA, 2002), *Guidance for Subaqueous Dredged Material Capping* (Palermo et al., 1998a), and *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al., 1998b), provide detailed procedures for site and sediment characterization, cap design, cap placement operations, and monitoring for subaqueous capping. These guidance documents serve as the technical basis for this White Paper and should be consulted for a more detailed discussion of the various topics. Figure 2 illustrates in flowchart format the major steps in evaluating and implementing an ISC remedy.

## FIGURE 2 DESIGN SEQUENCE FOR *IN-SITU* CAPPING PROJECTS




In addition to these documents, there are multiple references that discuss physical considerations, design, and monitoring requirements for capping. These include the following:

- *Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes* (Averett et al., 1990);
- *Design Requirements for Capping* (Palermo, 1991a);
- *Site Selection Considerations for Capping* (Palermo, 1991b);
- *Washington State Department of Ecology 1990 Standards for Confined Disposal of Contaminated Sediments Development Document* (Ecology, 1990);
- *Equipment and Placement Techniques for Capping* (Palermo, 1991c);
- *Monitoring Considerations for Capping* (Palermo et al., 1992);
- *Subaqueous Capping of Contaminated Sediments: Annotated Bibliography* (Zeman, et al., 1992); and
- *Design Considerations for Capping/Armoring of Contaminated Sediments In-Place* (Maynord and Oswalt, 1993).

The salient elements of site selection, design, construction, monitoring, and liability management from these references will be discussed in this paper. However, any proposed capping program should include a detailed consideration of those elements from the individually cited papers.

### 1.3.3 Advantages and Applicability of an ISC Alternative

A principle advantage of ISC is that contaminated sediments are isolated by the cap in-place and do not require removal. Because the capping operation covers the contaminated sediment, the potential for contaminant resuspension and the risks associated with dispersion of contaminated materials during construction is relatively low and comparable to environmental removal operations. Also, a major advantage is that no disposal site or *ex-situ* treatment for the dredged sediment is needed. Most capping projects use conventional and locally available materials, equipment, and expertise. For this reason, in certain cases the ISC option may be implemented more quickly and may be less expensive than options involving removal and disposal or treatment. Depending on the location of the cap, the type of construction, and the availability of materials, a cap may be readily repaired, if necessary.

A well-designed, properly constructed and placed on the contaminated surface, cap along with effective long-term monitoring and maintenance, can prevent bioaccumulation by providing long-term isolation of bottom-dwelling organisms from the contaminated sediments, and the prevention of contaminant flux into the surface water. Incorporation of habitat elements into the cap design can provide an improvement or restoration of the biological community.

The National Research Council (NRC, 1997) provided general guidance on where conditions would be favorable, or not favorable, for the consideration of ISC. Table 1 summarizes conditions favorable for capping (NRC, 1997) and corresponding conditions for the Lower Fox River.

### TABLE 1 SITE CONDITIONS THAT FAVOR ISCS AND THE CORRESPONDING CONDITIONS ON THE LOWER FOX RIVER

| Conditions Favorable for ISC (NRC, 1997) | Corresponding Conditions for the Lower Fox River |
|---|---|
| Contaminant sources have been sufficiently abated to prevent re-contamination of the cap. | Sediments are considered the major source of PCBs in the Lower Fox River. External sources of PCB inflow have been controlled. The potential for recontamination is low if capping is implemented as part of an overall remedial program and in a downstream sequence. |
| Contaminants are of moderate to low toxicity and mobility. | Only non-Toxic Substances Control Act (TSCA) areas will be considered for capping (see discussion below). |
| Monitored natural recovery (MNR) is too slow to meet RAOs in a reasonable time frame. | MNR may be appropriate for OUs 2 and 5, but is considered non-protective for OUs 1, 3, and 4. |
| Cost and/or environmental effects of removal are very high. | Construction costs of a complete removal of all PCBs to levels below sediment quality thresholds are high. |
| Suitable types and quantities of cap materials are available. | Capping materials are available within the general area of the Lower Fox River. |
| Hydrologic conditions will not compromise the cap. | The Lower Fox River is a hydraulically controlled River but still has potential for scour during flood events. Ice accumulations during winter could compromise cap integrity. Armor layers will be a required cap component. Selection of an ISC must consider dam maintenance as part of long-term institutional controls. |
| Weight of the cap can be supported by the original bed. | Capping has been successful at sites with physical sediment properties similar to conditions on the Lower Fox River. |
| Cap is compatible with current and/or future waterway uses. | Some areas within the OUs are incompatible with a capping remedy. Capping would be applied as a remedy component in combination with removal. |
| Site conditions are not favorable for complete removal of contaminated sediment. | Site conditions do not limit the applicability of a removal alternative. |

### 1.3.4 Disadvantages, Uncertainties, and Limitations of an ISC Alternative

A principal disadvantage of ISC is that contaminated sediment will be left in place and not removed from the River. Since ISC leaves the contamination source in place, the sediment is not treated or detoxified. It is often necessary to rely on institutional controls, which can be limited in terms of effectiveness and reliability, to protect the cap. Although the isolation and containment associated with capping can be effective for hundreds of years or longer, contaminants will slowly migrate from the deposit over time. Long-term cap performance monitoring and maintenance is therefore required, which can offset part of the capital cost savings over removal. Capping sites within the Lower Fox River may be subject to catastrophic events, such as major floods, ice scour, and dam removal or failure. These events have the potential to erode or undermine the cap, and should be factored into remedy selection, design, and monitoring.

To provide erosion protection, it may be necessary to use cap materials that are incompatible with native bottom materials and can alter the biological community. Depending on the site and cap design, it may be desirable to select capping materials that discourage colonization by native deep-burrowing organisms to limit bioturbation. In either case, the cap may be relatively poor habitat for the local biological community.

For sediments with high organic content, significant gas generation will occur due to anaerobic degradation. The influence of this process on cap effectiveness presents an uncertainty that is difficult to account for in modeling cap processes.

Some of the most important factors that should be present at a site to conclude that capping may be a feasible and appropriate remedy, include the ability of the *in-situ* contaminated sediment layer to support a man-made or naturally deposited cap, and the compatibility of capped deposit with waterway use.

In addition, institutional controls necessary to protect the cap, such as restrictions on fishing or anchoring, may not be reliable, and therefore may not be an effective means of enforcement. The cost of routine cap maintenance and repair should be included in the cost analysis. The potential for cap failure, and the subsequent need to remove portions of the cap, due to unanticipated site conditions or events should be considered in selecting areas to be capped. Also, there are very little data that currently exist on the long-term success of ISC projects.

Table 2 summarizes important factors which may rule out capping as a viable alternative and the corresponding conditions for the Lower Fox River.

## TABLE 2 SITE CONDITIONS THAT DO NOT FAVOR CAPPING AND THE CORRESPONDING CONDITIONS FOR THE LOWER FOX RIVER

| Conditions Which May Rule Out ISC (NRC, 1997) | Corresponding Conditions for Lower Fox River |
|---|---|
| Contaminant sources have not been sufficiently abated to prevent re-contamination of the cap. | Sediments are considered the major source of PCBs in the Lower Fox River. External sources of PCB inflow have been controlled. The potential for recontamination is low if capping is implemented as part of an overall remedial program and in a downstream sequence. |
| Unacceptable risk of catastrophic failure due to wave events, flood events, ice scour, slope failure, or seismic events. | Placement of an armor layer will be required for scour protection; cap layer will not be placed at elevations susceptible to ice scour. Dam failure may be a potential concern, but the cap armor could be designed with a factor of safety. |
| Contaminant mobility and transport conditions cannot be effectively controlled by a designed cap (e.g., some combination of high contaminant concentrations, presence of non-aqueous phase liquids (NAPL), and advective groundwater flow conditions). | Potential for gas (methane) formation is high and cap design must consider potential to affect the integrity of the cap, and incorporate appropriate safety and monitoring factors into the final design. Available information indicates little potential for seepage due to groundwater to the River. However, cap design must demonstrate that there are no sand-stringers with groundwater recharge to the River. |
| Public use of groundwater, if surface water recharges a shallow aquifer underneath the contaminated sediment. | Potable water is drawn from a different aquifer ca. 400-foot depth, with no hydraulic connection to the shallow aquifer. |
| Unacceptable short-term risk posed by placement of the cap. | Short-term risk of cap placement is likely to be equivalent to or less than that associated with environmental removal. Resuspension by cap placement must be considered in selecting the methods and equipment. |
| Presence of infrastructure, such as piers, bridges, or pipelines, that is incompatible with a permanent cap. | Extensive debris, abandoned, and existing infrastructure occurs within OU 4. Debris may preclude the construction of a continuous and effective cap and must be well delineated and considered in a final cap design. |
| Cap is incompatible with water body uses, such as navigation, flood control, or recreation. | Navigation channels are present and will be maintained at appropriate depths; caps will not be placed in navigation channel areas. |

### 1.3.5 Field Experience with Capping as a Sediment Remedy

A number of contaminated sediment sites have been remediated by ISC operations worldwide, and the experience base is growing rapidly. There has been a number of sediment capping projects in this country, mostly associated with USACE dredging or other non-Superfund projects. However, few projects to date have addressed capping highly contaminated sediment or highly mobile contaminants, or upward groundwater flow through a cap. In addition, most caps have been built within the last 10 years, and only a few of them have had intensive monitoring programs, so there are little data available on the long-term track record of contaminated sediment caps. However, the contaminant movement processes are for the most part well understood and tools are available to model the long-term behavior of contaminants under a cap.

A list of the major capping projects conducted to date is summarized in Table 3. With few exceptions, these projects have been located in North America. Almost all of the projects to date have been located in relatively deep, quiescent water bodies (e.g., lakes, estuaries, or ocean floor) and incorporated a relatively thick cap (ca. 18 inches or greater) based on consideration of physical mixing during placement, advective and diffusive flux, physical cap stability, and potential for bioturbation of the cap.

## 1.4 ISC FUNCTIONS AND PERFORMANCE OBJECTIVES

ISC remedies must be considered engineered projects, designed to meet specific functions and performance objectives. The design must consider the nature of the Site and all processes acting at the Site, which may influence the cap from the standpoint of its physical stability and its ability to isolate contaminants. These are discussed below.

### 1.4.1 Capping Functions and Design Criteria

The goal of ISC is to reduce exposure of aquatic organisms to sediment contaminants, thereby reducing contaminant uptake and providing appropriate protection of human health and the environment.

ISC can address remediation through three primary functions:

- Physical isolation of the contaminated sediment from the aquatic environment;
- Stabilization of contaminated sediment, preventing resuspension and transport to other sites; and
- Reduction of the flux of dissolved and colloidally transported (i.e., facilitated transport) contaminants into surface cap materials and the overlying water column.

The selected functions for a cap and design criteria for a specific capping project should be framed to support Remedial Action Objectives (RAOs), Remediation Goals (RGs) or selected cleanup levels.

## TABLE 3 SUMMARY OF CONTAMINATED SEDIMENT CAPPING PROJECTS

| Sediment Project | Chemicals of Concern | Site Conditions | Design Thickness (feet) | Cap Material | Year Constructed | Performance Results | Comments |
|---|---|---|---|---|---|---|---|
| ***Great Lakes Region*** | | | | | | | |
| Sheboygan River/Harbor Wisconsin | PCBs | | composite of geotextile on fabric, 6" aggregate, geotextile, 6" cobble, with the perimeter anchored with gabions | armored stone composite | 1989–1990 | • Undetermined cap effectiveness<br>• Some erosion of fine-grained material<br>• WDNR/EPA order cap removal in ROD | Demonstration bench-scale project. Composite armored cap required as sediments were located in high-energy river environment. Gabions placed around the corners for anchoring. Additional course material placed into voids/gaps. |
| Wausau Steel Site Wisconsin | lead, zinc, mercury | Oxbow on the Big Rib River, nearshore cap | 2 | composite: sand over geotextile | 1997 | • Chemical isolation failed<br>• Cap not physically stable | Methane gas trapped under the geotextile forced cap to rise in the center, pulling away geotextile from the edge. Sand erosion also occurred in the nearshore areas. |
| Manistique Capping Project Michigan (pilot) | PCBs | | 40-mil (0.1') | HDPE | 1993 | • Physical inspection of the temporary cap approximately 1 year after installation showed cap was physically intact and most anchors still in place, but was methane-filled | A 240' by 100' HDPE temporary cap was anchored by 38 2-ton concrete blocks placed around the perimeter of the cap. This temporary cap was installed to prevent erosion of contaminated sediments within a river hotspot with elevated surface concentrations. |
| Hamilton Harbor Ontario, Canada | PAHs | | 1.6 | sand (2.5 acres) (*in situ*) | 1995 | • Chemical isolation effective<br>• No erosion of cap | Cap monitoring in porewater ongoing. |

# TABLE 3 SUMMARY OF CONTAMINATED SEDIMENT CAPPING PROJECTS

| Sediment Project | Chemicals of Concern | Site Conditions | Design Thickness (feet) | Cap Material | Year Constructed | Performance Results | Comments |
|---|---|---|---|---|---|---|---|
| ***Puget Sound*** | | | | | | | |
| Duwamish Waterway Seattle, Washington | heavy metals, PCBs | | 1–3 | sand (4,000 cy) | 1984 | • Chemical isolation effective<br>• No erosion of cap | Monitoring as recent as 1996 showed cap remains effective and stable. Split-hull dump barge placed sand over relocated sediments (CAD site) in 70' water. |
| One Tree Island Olympia, Washington | heavy metals, PAHs | | 4 | sand | 1987 | • Chemical isolation effective<br>• No erosion of cap | Last monitoring occurred in 1989 showed that sediment contaminants were contained. |
| St. Paul Waterway Tacoma, Washington | phenols, PAHs, dioxins | | 2–12 | coarse sand | 1988 | • Chemical isolation effective<br>• Cap within specifications | Some redistribution of cap materials has occurred, but overall remains >1.5 m (4.9'). *C. californieus* found in sediments, but never >1 m (3.3'). |
| Pier 51 Ferry Terminal Seattle, Washington | mercury, PAHs, PCBs | | 1.5 | coarse sand (4 acres) (*in situ*) | 1989 | • Chemical isolation effective<br>• Cap within specifications<br>• Recolonization observed | As recent as 1994, cap thickness remained within design specifications. While benthic infauna have recolonized the cap, there is no indication of cap breach due to bioturbation. |
| Denny Way CSO Seattle, Washington | heavy metals, PAHs, PCBs | water depth 18'–50' | 2–3 | sand (3 acres) | 1990 | • Chemical isolation effective<br>• Cap within specifications<br>• Recolonization observed | Cores taken in 1996 show that while cap surface chemistry shows signs of recontamination, there is no migration of isolated chemicals through the cap. |
| Piers 53–55 CSO Seattle, Washington | heavy metals, PAHs | | 1.3–2.6 | sand (4.5 acres) (*in situ*) | 1992 | • Chemical isolation effective<br>• Cap stable, and increased by 15 cm (6") of new deposition | Pre-cap infaunal communities were destroyed in the rapid burial associated with cap construction, but had recovered by 1996. The initial community established in the sand over time shifted as fine-grained material was redeposited on the cap. |
| Pier 64 Seattle, Washington | heavy metals, PAHs, phthalates, dibenzofuran | | 0.5–1.5 | sand | 1994 | • Some loss of cap thickness<br>• Reduction in surface chemical concentrations | Thin-layer capping was used to enhance natural recovery and to reduce resuspension of contaminants during pile driving. |
| GP lagoon Bellingham, Washington (*in situ*) | mercury | shallow intertidal lagoon | 3 | sand | 2001 | • Chemical isolation effective at 3-months<br>• Cap successfully placed | Ongoing monitoring. |
| East Eagle Harbor/Wyckoff Bainbridge Island, Washington | mercury, PAHs | | 1–3 | sand (275,000 cy) | 1994 | • Chemical isolation effective<br>• Cap erosion in ferry lanes<br>• Some recontamination observed due to off-site sources | Cap erosion measured within first year of monitoring only in area proximal to heavily-used Washington ferry lane. Chemicals also observed in sediment traps. Ongoing monitoring. |
| West Eagle Harbor/Wyckoff Bainbridge Island, Washington (*in situ*) | mercury, PAHs | 500-acre site | Thin cap 0.5' over 6 acres and thick cap 3' over 0.6 acre | sand (22,600 tons for thin cap and 7,400 tons for thick cap) | partial dredge and cap 1997 | • Chemical isolation effective | To date, post-verification surface sediment samples have met the cleanup criteria established for the project. Ongoing monitoring. |

## TABLE 3 SUMMARY OF CONTAMINATED SEDIMENT CAPPING PROJECTS

| Sediment Project | Chemicals of Concern | Site Conditions | Design Thickness (feet) | Cap Material | Year Constructed | Performance Results | Comments |
|---|---|---|---|---|---|---|---|
| ***California and Oregon*** | | | | | | | |
| PSWH<br>Los Angeles, California | heavy metals, PAHs | | 15 | sand | 1995 | • No data to date | Overall effective cap was >15'. This was not a function of design, but rather a function of the low contaminated-to-clean sediment volume. |
| Convair Lagoon<br>San Diego, California | PCBs | 5.7-acre cap in 10-acre site; water depth 10'–18' | 2' of sand over 1' rock | sand over crushed rock | 1998 | • Chemical isolation effective<br>• Cap was successfully placed<br>• Some chemicals observed in cap | Ongoing monitoring for 20 to 50 years including diver inspection, cap coring, biological monitoring. |
| McCormick and Baxter<br>Portland, Oregon | heavy metals, PAHs | 15 acres of nearshore sediments and soils | NA | sand | planned, but not constructed | • No data to date | Long-term monitoring, OMMP, and institutional controls were also specified. |
| ***New England/New York*** | | | | | | | |
| Stamford-New Haven-N<br>New Haven, Connecticut | metals, PAHs | | 1.6 | sand | 1978 | • Chemical isolation effective | Cores collected in 1990. |
| Stamford-New Haven-S<br>New Haven, Connecticut | metals, PAHs | | 1.6 | silt | 1978 | • Chemical isolation effective | Cores collected in 1990. |
| New York Mud Dump Disposal Site<br>New York | metals (from multiple harbor sources) | | unknown | sand (12 million cy) | 1980 | • Chemical isolation effective | Cores taken in 1993 (3.5 years later) showed cap integrity over relocated sediments in 80' of water. |
| Mill-Quinniapiac River<br>Connecticut | metals, PAHs | | 1.6 | silt | 1981 | • Required additional cap | Cores collected in 1991. |
| Norwalk, Connecticut | metals, PAHs | | 1.6 | silt | 1981 | • No problems | Routine monitoring. |
| Central Long Island Sound Disposal Site (CLIS)<br>New York | multiple harbor sources | | unknown | sand | 1979–1983 | • Some cores uniform structure with low-level chemicals<br>• Some cores chemical isolation effective<br>• Some slumping | Extensive coring study at multiple mounds showed cap stable at many locations. Poor recolonization in many areas. |
| Cap Site 1<br>Connecticut | metals, PAHs | | 1.6 | silt | 1983 | • Chemical isolation effective | Cores collected in 1990. |
| Cap Site 2<br>Connecticut | metals, PAHs | | 1.6 | sand | 1983 | • Required additional cap | Cores collected in 1990. |
| Experimental Mud Dam<br>New York | metals, PAHs | | 3.3 | sand | 1983 | • Chemical isolation effective | Cores collected in 1990. |
| New Haven Harbor<br>New Haven, Connecticut | metals, PAHs | | 1.6 | silt | 1993 | • Chemical isolation effective | Extensive coring study. |
| Port Newark/Elizabeth<br>New York | metals, PAHs | | 5.3 | sand | 1993 | • Chemical isolation effective | Extensive coring study. |

# TABLE 3 SUMMARY OF CONTAMINATED SEDIMENT CAPPING PROJECTS

| Sediment Project | Chemicals of Concern | Site Conditions | Design Thickness (feet) | Cap Material | Year Constructed | Performance Results | Comments |
|---|---|---|---|---|---|---|---|
| 52 Smaller Projects New England | metals, PAHs | | 1.6 | silt | 1980–1995 | • Chemical isolation effective | Routine monitoring. |
| ***Other North American Projects*** | | | | | | | |
| Soda Lake, Wyoming | oil refinery residuals | soft, unconsolidated sediments | 3 | sand | 2000 | • Chemical isolation effective | Demonstration project that showed successful placement over soft sediments and isolation of PAHs and metals in refinery residuals. |
| ***International Projects*** | | | | | | | |
| Rotterdam Harbor Netherlands | oils | water depth 5 to 12 m | 2–3 | silt/clay sediments | 1984 | • No available monitoring data | As pollution of groundwater was a potential concern, the site was lined with clay prior to sediment disposal and capping. |
| Hiroshima Bay Japan | | Water depth 21 m | 5.3 | sand | 1983 | • No available data | |


**References:**

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USACE, 1995. *Sediment Capping of Subaqueous Dredged Material Disposal Mounds: An Overview of the New England Experience 1979–1995*. Special Technical Report Contribution 95. United States Army Corps of Engineers, New England Division, Disposal Area Monitoring System (DAMOS). August.

If reduction in flux is an intended function of the cap, the following processes should be considered when evaluating the potential effectiveness of a cap and in developing design criteria for the cap:

- Upward contaminant flux rates (mass of contaminant/unit area/unit time);
- Pore water concentrations (dissolved or colloidal);
- Potential changes in redox potential (contaminant chemistry) due to cap placement;
- Long-term accumulation of contaminants in cap material;
- Contaminant breakthrough as a function of time; and
- Ability of the cap to withstand bioturbation and erosive forces.

For example, contaminant flux and the resulting impact on cap surface materials, cap pore water, or overlying water quality can be compared to site-specific sediment cleanup levels or water quality standards (e.g., federal ambient water quality criteria or state-promulgated standards). In addition, the concentration of contaminants accumulating in the cap material as a function of time can be compared to site-specific target cleanup levels during long-term cap performance monitoring. The design should also be compatible with available construction and placement methods, and the mitigation of potential habitat impacts during construction.

### 1.4.2 Lower Fox River Design and Performance Criteria

For the Lower Fox River, the design criteria for capping should include the following:

- Technical, regulatory and institutional issues will be appropriately considered in identifying potential areas for capping.
- The cap will be designed to provide physical isolation of the PCB-contaminated sediments from benthic organisms.
- The cap will be physically stable from scour by currents, flood flow, and ice scour. The 100-year flood event will be considered in these evaluations.
- The cap will provide isolation of the PCB-contaminated sediments in perpetuity from flux or resuspension into the overlying surface waters. The performance criteria for chemical isolation will be a limit of 250 parts per billion (ppb) of PCBs in the cap sediment (dry-weight basis) in the biologically active zone, defined as the upper 10 centimeters (cm) of the isolation layer of the cap. This standard would apply as a construction standard to ensure the cap is initially placed as a clean layer, and would also apply as a long-term limit with respect to chemical isolation.

- The cap design will consider operational factors such as the potential for cap and sediment mixing during cap placement and variability in the placed cap thickness.

- The cap design will incorporate an appropriate factor of safety to account for uncertainty in Site conditions, sediment properties, and migration processes.

# 2 SITE AND SEDIMENT CHARACTERISTICS

Site conditions, more than any other consideration, will determine the feasibility and effectiveness of ISC. Site characteristics affect all aspects of a capping project, including design, equipment selection, and monitoring and management programs. Some limitations in site conditions can be accommodated in the ISC design. A thorough examination of site conditions should determine if further consideration of ISC is appropriate. For the Lower Fox River, site characteristics will dictate which areas can be potentially capped within the OUs.

Aspects of site characterization important for ISC include the following:

- Physical environment;
- Hydrodynamic conditions;
- Geotechnical/geological conditions;
- Hydrogeological conditions;
- Sediment characteristics; and
- Waterway uses.

Each of these are discussed in the context of the Lower Fox River in the following sections.

## 2.1 PHYSICAL ENVIRONMENT

Regional, climate, and basic environmental settings for the project are important considerations as well as specific physical environmental characteristics as they may relate to cap design. The Lower Fox River is a well-studied system with a large data set that is summarized in the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002b). The basic environmental setting for the Lower Fox River is a controlled series of locks and dams, with the exception of the last OU of the River. The level of control is high for OUs 1, 2, and 3, but less so for OU 4. The dimensions of the waterway are not generally a constraint to capping except for certain limitations regarding water depth.

Other physical environment considerations that are of importance for the Lower Fox River include long-term lake level fluctuations; the presence of several bridge and infrastructure crossings; and a number of piers, docks, and other shoreline structures. The locale of the Lower Fox River is subject to ice formation, and the effects of ice scouring must be considered. The relevance of each of these considerations and the site-specific conditions for the Lower Fox River are discussed below.

### 2.1.1 Water Depth and Bathymetry

Water depths and seiche patterns could limit cap construction options and will affect cap design and waterway uses. The potential for ice scour and habitat characteristics are the two most important considerations related to water depth for capping on the Lower Fox River. WDNR has indicated that ice scour could be a constraint on cap placement in water depths of 3 feet or less. Carp habitat is considered undesirable for the Lower Fox River, and to discourage its creation, a minimum water depth of 3 feet should be maintained. Long-term lake level changes (from +5 to -1) should be accounted for in designing for these restrictions for OU 4. Considering these restrictions, no cap should be constructed with a surface above -3 feet chart datum in OUs 1 and 3, and above -4 feet chart datum in OU 4. Removal may therefore be required prior to ISC placement in shallow-water areas.

With the exception of the bank areas, bathymetry of the Lower Fox River is relatively flat and should present no restrictions on cap placement. Steeper slopes are evident near the banks, but bank areas represent only a small percentage of the total area to be remediated.

The water depths in OU 1 are generally shallow (less than 6 feet) throughout the area to be remediated and may present some constraints for equipment access for cap placement. Shallow draft barges for movement of cap material or hydraulic placement methods using pipeline could be considered. The other two operable units do not have any general depth restraints for capping.

### 2.1.2 Hydrodynamic Conditions

Capping projects are easier to design in low-energy environments (e.g., protected harbors, low-flow streams, or estuarine systems). In open water, deeper sites will be less influenced by wind or wave-generated currents, and are generally less prone to erosion than shallow, nearshore environments. However, armoring techniques or selection of erosion-resistant capping materials can make capping technically feasible in some high-energy environments.

Hydrodynamic conditions differ between OUs 1, 3, and 4, but the site can be generally characterized as a low-energy environment. Although the Lower Fox River is an alluvial river and sediments are subject to transport during flood events, the presence of locks and dams provides for a controlled environment. The lower portion of OU 4 is open to Green Bay and is subject to seiches and long-term lake level changes.

The shear stress distribution during flood events has been modeled (HydroQual, 2000; LTI, 2002). However, there are some differences between the modeling efforts regarding interpretations of data and the resulting erosion potential. The shear stresses predicted to occur during flood events indicates that the use of erosion-resistant materials (armor layers) for the upper portions of the cap will be needed. Since the shear stress varies significantly with geometry across the River cross section and upstream to downstream within OUs, a single armor design over the entire project is not sufficient.

The hydrodynamics of the Lower Fox River should be definitively evaluated as part of the detailed design for the armor component of the cap. This design should be based on an evaluation of a 100-year flood event.

The presence of an ISC can alter existing hydrodynamic conditions. So, the flow-carrying capacity of the River should also be evaluated for the post-remedy condition (with removal and capping components considered).

### 2.1.3 Sedimentation

In a net depositional environment, the effect of new sediment deposited on the cap should be considered. Clean sediment accumulating on the cap or in voids within an armor layer can increase the isolation effectiveness of the cap over the long term. Accumulation of contaminated sediment from off-site sources can result in a contaminated surface layer over the cap. The sources of PCBs would be controlled for the system by implementing the construction of any remedy progressing from upstream to downstream. Deposition of new sediment should be considered when designing the monitoring program.

### 2.1.4 Dam Safety and the Potential for Dam Removal

The safety of the dams with respect to potential failure is an issue for cap placement and design of the armor layer for the cap. Furthermore, the removal of a dam for safety or environmental reasons should be considered in cap design, and in the long-term institutional requirements for cap operations and monitoring.

As noted previously, the hydrodynamics of the Lower Fox River are influenced by the series of locks and dams on the River. Within Wisconsin, there are approximately 3,700 dams. An additional 700 dams have been built and washed out or removed since the late $19^{th}$ century, and approximately 100 dams have been removed since 1967. On the Lower Fox River, there are 13 existing dams and 1 abandoned dam. As documented in *White Paper No. 4 – Dams in Wisconsin and on the Lower Fox River* (WDNR, 2002a), the current condition of the dams is stable. Recent inspection reports by the USACE indicate that the spillway and sluiceway sections of the dams have adequate compression to resist overturning and have adequate bearing capacity to support the maximum base pressure. While inspections did reveal various potential problems, such as the need for concrete repairs, the overall conclusion of the reports was that dams were found to be in good condition overall and no structural deficiencies were found which would affect the operation of the dam. Many of the inspection reports recommended development of a plan to prioritize the repairs for the dams on the Lower Fox River over a subsequent 5-year period.

The three major reasons for dam removals in Wisconsin are:

- Removal of an unsafe structure under Chapter 31.19 of state statutes. Under Chapter 31.19, the WDNR is required to inspect “large” dams at least once every 10 years to ensure their safety.
- Chapter 31.187 charges the WDNR with removing “abandoned” dams when either no owner is found, or the owner or owners are not able to fund repairs.
- In a few cases, the state has removed, or proposed to remove, dams that have a significant environmental impact. Many of those have been on WDNR properties.

While dam removal is not imminent or planned along the Lower Fox River, dam removal considerations are evident in two national PCB sediment programs. On the Hudson River, the Fort Edward dam was removed in 1973 due to structural instability. The so-called remnant deposits in the Hudson River are areas of former river bottom that became exposed due to changes in the water level following removal of the dam (EPA, 1984). Changes in the hydrology after dam removal resulted in the downstream release of an estimated 1,300,000 cy of PCB-laden sediment (NOAA, 2002).

In Michigan, a series of dams are under consideration for removal on the Kalamazoo River (USGS, 2001). Removal of these dams will return the Kalamazoo River to its pre-dam flow, increase recreation uses and safety of the River, and improve aquatic habitat in that section of the River. However, there are large volumes of PCB-contaminated sediments within the impoundments behind the dams; the Michigan Department of Environmental Quality, EPA, and the USGS are all involved in evaluating the management of those sediments if dam removal were to occur.

Any consideration for an ISC on the Lower Fox River should consider the maintenance of the dam/lock system as an institutional control with requirements for maintenance of the system in perpetuity. It is worth noting that this requirement was similarly considered for breakwaters in evaluating capping as an option for Manistique Harbor. As an alternative, the ISC cap design should include a component for safe isolation if dam removal results in the creation of remnant deposits.

### 2.1.5 Geological and Hydrogeological Conditions

The geological conditions within the Lower Fox River are well documented in Section 3 of the RI, and are not discussed here. Pertinent to any capping evaluation is the thickness of contaminated sediments. Within OU 1, the major deposits are generally between 1 and 3 feet of accumulated sediments. In OU 3, the longest deposit, EE, ranges up to 7.5 feet in thickness, while accumulations immediately behind the De Pere dam exceed that. Within OU 4, sediment thickness varies with approximately 3-foot accumulations closer to the dam, and 12 to 19 feet of accumulation in the areas proximal to the turning basin.

A detailed evaluation and understanding of the site's hydrogeology is a critical component in evaluating the acceptability of an ISC and a prerequisite to proper cap design. The presence of an upward groundwater gradient at the site would require that the cap be designed to accommodate advective processes related to contaminant migration.

The Lower Fox River is fairly well documented to have either relatively nonporous clay or bedrock underlying most of the River. However, the area does include sand stringers or fractured bedrock; these would need to be considered during sampling for design purposes. Available information indicates little potential seepage (advection) due to groundwater flow, so no continuous advective flow processes need be considered for the cap design. However, the process of consolidation-induced advection will occur and should be considered in the cap design.

## 2.2 SEDIMENT CHARACTERISTICS

### 2.2.1 Sediment Physical Properties

Physical characteristics of the River and Green Bay are presented in detail in Section 3 of the RI. In general, sand and silt are the dominant grain sizes in the River sediments, typically accounting for between 75 and 90 percent of the particles present. In OUs 1, 2, and 4, silts comprise about 40 percent of the sediments, while sand content ranges between 41 and 46 percent. In OU 3, however, the silt content is 54 percent, while sand comprises only about 23 percent of the sediments. Within a single unit, the distributions are variable. For example, within OUs 1 and 4 the grain size may average between 36 and 40 percent sand, but the individual samples collected show a range from 0.5 to 98 percent sand.

One of the barriers to effective cap design is the general lack of data taken on physical parameters, such as bulk density, percent moisture, Atterberg limits, and the absence of any data from self-consolidation tests. Only a limited number (less than 20 data points) of these data exist, and thus it is difficult to assign specific design and performance properties at this stage. It will be necessary to acquire those data prior to finalizing any ISC design for the River. From the data in hand, however, two points are clear: (1) no single design will be adequate for the entire River and the cap engineering will need to be specific to the deposit intended, and (2) caps have been successfully implemented over sediments that have similar physical properties to those found on the Lower Fox River.

### 2.2.2 Extent of Contamination

The physical, chemical, and biological characteristics of the contaminated sediment, both horizontally and vertically, have been defined in Section 5 of the RI. Within the Proposed Plan, WDNR and EPA defined the Remedial Action Level (RAL) as 1 ppm, with an expected surface-weighted average concentration within each OU of between 0.25 and 0.35 ppm. For OUs 1 and 3, over 90 percent of PCB mass is in the upper 1 meter of sediment. In OU 4, 90 percent of the PCB mass is in the upper 2 meters of sediment (in 60 percent of OU 4, the average depth of dredging to the 1,000 ppb concentration is the top meter, 90 percent in the top 2 meters) is generally in the upper few feet of sediment. New data for OU 1 submitted with the public comments was evaluated in *White Paper No. 2 – Evaluation of New Little Lake Butte des Morts PCB Sediment Samples* (WDNR, 2002b). An analysis of these data concluded that the new information did not alter the current understanding of the general conditions within the unit, nor substantively effect the need for remedial actions.

The presence of PCBs with concentrations exceeding 50 ppm presents some constraints for capping with respect to TSCA. The ability of an ISC to meet the requirements of TSCA has not been fully established. TSCA-level sediments are present only in limited areas of OUs 1, 3, and 4. Based on these considerations, no capping of TSCA-level sediments should be considered.

Additional sampling at a greater degree of resolution will be needed for the design phase.

### 2.2.3 Shear Strength

Shear strength of contaminated sediment deposits is of particular importance in determining the feasibility of ISC from the standpoint of cap placement. The soft sediments will require due care in selecting placement techniques and management of capping operations. No shear strength data have yet been collected. Vane shear data should be collected during the design phase to determine the distribution of shear strengths by area and vertically within the sediment profile.

### 2.2.4 Gas Formation

When contaminated materials or sludges containing organic material are capped, the organic material could begin to decompose under the influences of anaerobic and pressure-related processes. The products of this decomposition process will consist mainly of methane and hydrogen sulfide gases. As these dissolved gases accumulate and transfer into a gaseous phase, they could begin to percolate through the capped matrix by convective or diffusive transport. This transport of gases percolating through the cap can facilitate a more rapid contaminant migration by providing avenues for contaminant release or solubilizing the contaminants of concern, carrying them through the saturated porous media dissolved in the gaseous molecules.

Methane generation must be considered for the Lower Fox River. The Lower Fox River has a high methane sediment that is documented in the 1996 RI/FS (GAS/SAIC, 1996). Sub-bottom profiles of sediments revealed large subsurface accumulations of methane in OUs 1, 2, and 3. Methane releases are frequently observed during sediment sampling, and were seen during the demonstration project at SMU 56/57.

### 2.2.5 Debris and Obstructions

Debris is present in the nearshore areas of the OUs, especially in OU 4. Debris may preclude the construction of a continuous and effective cap and must be well delineated and considered in a final cap design. A side-scan sonar survey is planned to determine the extent of debris in the sediment.

## 2.3 WATERWAY USES

### 2.3.1 Flow Capacity

Placement of a cap (without prior removal action) will reduce water depths and the flow carrying capacity of the River. Chapter 116, Wisconsin Administrative Code, Wisconsin’s Floodplain Management Program, details the regulations for construction and development in floodways and floodplains. Any proposed cap would have to meet the substantive requirements of Section 116.16(1), which requires that structures built within floodways and floodplains must be built to withstand flood depths, pressures, velocities, impact, uplift forces, and other factors associated with the regional (100-year) flood. In addition, any cap proposed would be required to undertake a determination on the potential effects on the regional flood heights. This would require a substantive study on the hydrologic and hydraulic conditions pre- and post-construction to determine if there would be an increase in flood height due to cap placement. NR 116.03(28) defines an “increase in regional flood height” as being equal to or greater than 0.01 foot if a cap would result in an increase in regional flood height.

### 2.3.2 Navigation and Recreational Use

A navigation channel system exists in OUs 1, 3, and 4 which must be considered in determining potential capping areas. The USACE maintains an 18-foot-deep commercial channel in OU 4. For OUs 1 and 3, the USACE no longer maintains the authorized channel depth and there is no longer commercial traffic in these OUs. However, the WDNR has indicated that there will be future demand to maintain a 6-foot deep channel in OUs 1 and 3 for recreational use. Based on these considerations, there does not appear to be any need to consider modifying the authorization from commercial to recreational, if the state wishes to maintain the recreational channel depth. The continued demand to maintain the existing channel depths would preclude cap placement within the channel areas.

The acceptable draft of vessels allowed to navigate over a capped area depends on water level fluctuations and the potential effects of vessel groundings on the cap. Due to potential cap erosion caused by propeller wash, engine size restrictions could also be needed. Anchoring should not be allowed at locations on or near the ISC site. Fishing and swimming may have to be restricted to avoid vessels from dragging anchors across the cap.

### 2.3.3 Infrastructure

Utilities (storm drains) and utility crossings (water, sewer, gas, oil, telephone, cable, and electrical) are commonly located in urban waterways. Existing utility crossings under portions of waterways to be capped may have to be relocated if their deterioration or failure might impact cap integrity or if they could not be repaired without disturbing the cap. Future utility crossing could be prohibited in the cap area. The presence of the cap can also place constraints on any future waterfront development that could require dredging in the area.

Infrastructure considerations for the Lower Fox River which could affect selection of areas to be capped and future cap integrity and maintenance include the following:

- Water supply intakes;
- Stormwater or effluent discharge outfalls;
- Utilities and utility crossings; and
- Construction of bulkheads, piers, docks, and other waterfront structures.

To date, environmental agencies have little experience with the ability to enforce use restrictions necessary to protect the integrity of an ISC (e.g., vessel size limits, bans on anchoring, etc.). Voluntary restrictions on public land and water use will likely be ineffective local enforcement of specific use restrictions is the desired outcome. Compliance, enforcement, and the effectiveness of these measures, and the consequences of non-compliance should be considered.

### 2.3.4 Habitat Considerations

ISC will alter the aquatic environment. Both potential improvement in habitat and change in the habitat type should be considered in evaluating and designing a capping alternative, wherever possible. However, it is important to remember that under CERCLA, the principal consideration is protection of human health and the environment, and capping is principally considered a remediation strategy. If a cap can be designed with beneficial habitat characteristics, that is a positive added benefit. In the case of the Lower Fox River, there is a separate Natural Resource Damage Assessment process that will address habitat restoration throughout the River and Green Bay. Nevertheless, this section does cover some habitat considerations for capping.

Where possible, the cap design should consider habitat for bottom-dwelling organisms or wetland wildlife. The desirable habitat characteristics will vary by location. In marine or estuarine environments, simply providing a layer of appropriately sized rock or rubble that can serve as hard substrate for attached molluscs (e.g., oysters or mussels) can enhance the ecological value. In freshwater systems, sand is neither a suitable substrate for benthic or epibenthic organisms, or for establishing submerged or emergent aquatic vegetation. A mix of cobbles and boulders can be chosen for aquatic environments in areas with substantial flow in order to support diverse assemblages of benthic infauna (e.g., Ephemeroptera, Plecoptera and Trichoptera) that in turn are prey for numerous fish species. The project manager should consult with local resource managers or natural resource trustee agencies to determine what types of modifications to the cap surface would provide suitable substrate for local organisms.

No matter what modification is desirable, the potential for attracting burrowing organisms incompatible with the cap design or ability to withstand additional physical disturbances should be considered. Habitat enhancements should not impair the function of the cap or its ability to survive storms, flooding, or propeller wash.

The Lower Fox River is a freshwater system, and the habitat is largely dominated by soft sediments. A cap as a habitat enhancement or detriment will depend upon the elevation of the final cap surface, the current velocity at the specific location, and the type of material selected for the armored surface. For example, a course sand cap placed in deeper portions of Little Lake Butte des Morts (greater than 4 feet) is more likely to be a short-term detriment, as sand does not provide habitat to benthic organisms that support fish species. A fine gravel armor in a low-velocity area of the River will not provide suitable substrate for benthos, nor would it serve as a spawning habitat for walleye because of sedimentation over eggs. Raising the river bottom by capping to shallow depths (less than 3 feet) would also have a detrimental effect, as it would create additional carp habitat. The short-term net environmental effect of that cap would also be negative, eliminating soft-sediment benthic production.

The importance of habitat to the River and Green Bay is evident in the advocacy by the Green Bay Remedial Action Plan for improved habitat in the form of extensive areas of rooted aquatics. Centrarchid (bass, crappie, sunfish) production is low within the Lower Fox River. The limiting factor for centrarchid production in the River is the general lack of rooted aquatic macrophyte beds that provide early life-stage habitat (Becker, 1983; Lychwick, personal communication).

In appropriately selected areas, armoring could enhance fish habitat. Walleye in the Lower Fox River and Green Bay prefer to spawn over large gravel and cobble with the greatest success occurring over 2- to 6-inch material (Lychwick, personal communication). This material was successfully employed by the WDNR in construction of walleye spawning enhancement areas in the River below the De Pere dam.

Alteration of habitat by cap placement is an issue for the Lower Fox River which will present a constraint with respect to reduction of water depths. Water levels should remain 3 feet or greater to discourage carp habitat and ice scour (see discussion above for water depth constraints). Long-term lake level changes should also be accounted for. Lake level changes generally vary from elevation +5 to -1 foot chart datum. Based on these factors, no cap can be constructed with a surface elevation above -4 feet chart datum. (Note that present GIS map is tied to -3 feet below chart datum.)

## 2.4 CONSIDERATIONS FOR SELECTING CAPPING AREAS FOR THE LOWER FOX RIVER

Based on the above site and sediment characteristics, the following constraints in defining proposed locations suitable for capping within OUs 1, 3, and 5 are provided:

- Outside of navigation channels (with an appropriate buffer) to allow for future slope dredging;
- Outside of areas with interfering infrastructure such as pipelines, utility easements, bridge piers, etc. (with an appropriate buffer);
- PCB concentrations below TSCA levels; and
- Sufficient water depth such that the cap surface elevation would be no greater than -3 feet chart datum for OUs 1 and 3 and -4 feet chart datum for OU 4 without prior deepening to allow for cap placement.

# 3 *IN-SITU* CAP DESIGN AND CONSTRUCTION

To meet remedial goals and objectives, an ISC project must be treated as an engineering project, with careful consideration to design, construction, and monitoring. Site-specific constraints must be considered when selecting construction methods and capping materials. Construction should conform to project specifications. Cap improvements may be necessary to address field constraints and other requirements. Short-term risks can increase on- or off-site during and immediately following remediation due to construction-related disturbance and potential for contaminant transport. Therefore, designs must include plans to mitigate and monitor impacts during and after construction.

The composition, dimensions, and thickness of the components of a cap can be referred to as the cap design. This design should address the intended functions and design or performance standards of the cap. The general steps for ISC design are shown in the flowchart on Figure 3, and include the following:

- Identify candidate capping materials and compatibility with contaminated sediment at the site;

- Assess the bioturbation potential of local bottom-dwelling organisms, and design a cap component to physically isolate sediment contaminants from them;

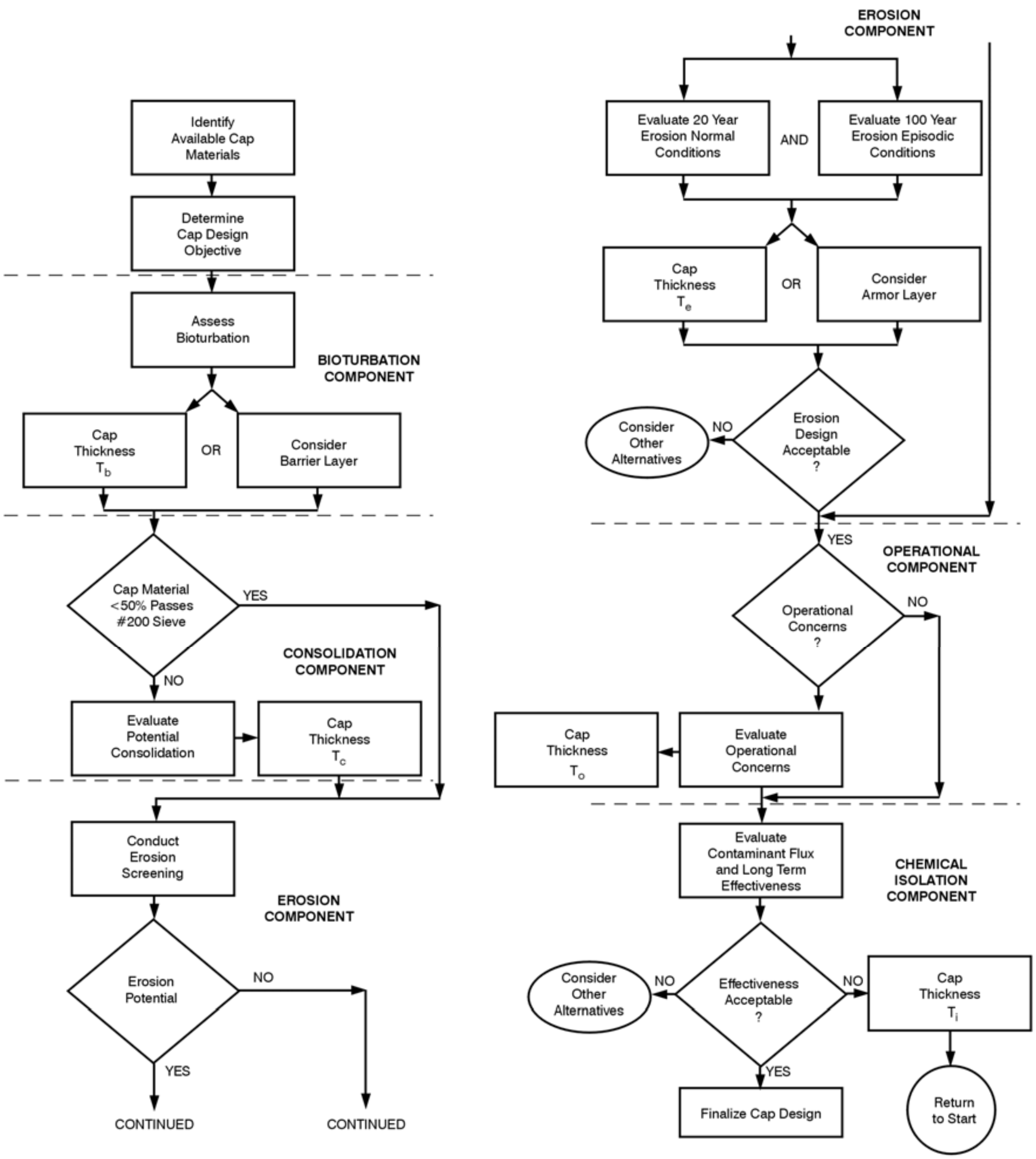
- Evaluate the potential erosion at the capping site due to currents, waves, ice scour, and propeller wash, and design a cap component to stabilize the contaminated sediment and other cap components;

- Evaluate the potential flux of sediment contaminants, and design a cap component to reduce the flux of dissolved contaminants into the water column;

- Evaluate the potential interactions and compatibility among cap components, including mixing and consolidation of compressible materials; and

- Evaluate the operational considerations and determine restrictions or additional protective measures (e.g., institutional controls) needed to ensure cap integrity.

## FIGURE 3 *IN-SITU* CAP DESIGN FLOWCHART




$T_t$ = Total Cap Thickness

- $T_b$ = thickness for bioturbation
- $T_c$ = thickness for consolidation
- $T_e$ = thickness for erosion
- $T_o$ = thickness for operational considerations
- $T_i$ = thickness for physical/chemical isolation

$T_t = T_b + T_c + T_e + T_o + T_i$

Both the FS and the Panel Report assume or propose a generic, representative cap design. Neither of these designs was evaluated in sufficient detail to constitute a "final" design suitable for all OUs of the River under all critical conditions. Similarly, it is not the purpose of this White Paper to present a proposed final design. Rather, design requirements and considerations are discussed here and needs for the final design are presented.

## 3.1 IDENTIFICATION/SELECTION OF CAPPING MATERIALS

Caps are generally composed of clean granular materials, such as sediment or soil; however, more complex cap designs could be required to meet site-specific RAOs. The design should consider the need for effective short- and long-term chemical isolation of contaminants, bioturbation, consolidation, erosion, and other related processes. For example, if the potential for erosion of the cap is significant, the cap thickness could be increased using a material with larger grain size, or an armor layer could be incorporated into the design. Porous geotextiles do not contribute to contaminant isolation, but serve to reduce the potential for mixing and displacement of the underlying sediment with the cap material. Geotextiles can also add structural support during cap placement. A cap composed of naturally occurring sand is generally preferred over quarry run sand, because the associated fine fraction and organic carbon content found in natural sands are more effective in providing chemical isolation by sequestering contaminants as they pass through the cap. Also, specialized materials may be considered for caps to enhance the chemical isolation capacity. Examples include engineered clay aggregate materials (e.g., AquaBlok™ or geosynthetic clay liners). These approaches are recent developments. However, the potential for gas generation may inhibit or prohibit use of impermeable components such as AquaBlok™ or membranes. Examples of cap designs considered and used for ISC are illustrated on Figure 1.

In designing cap thickness, consideration has to be given to the relative grain size, which affects the overall permeability of the ISC. In general, medium to fine sands have been used for ISCs. For example, the East Eagle Harbor Superfund Site ISC was constructed using medium sand (0.125 to 0.25 mm) dredged from within a river (EPA and USACE, 1995). Other recent ISC projects in the west/midwest have used a sand specification as follows:

| Sieve | Percent Passing |
|---|---|
| #40 (0.425 mm) | 99 |
| #60 (0.25 mm) | 20 |
| #200 (0.075 mm) | 3 |

This material could be described as a poorly graded fine sand. In at least one case, where finer sands were not commercially available, the design was modified to allow placement of somewhat coarser material for the initial 15 inches in a 24-inch cap, and then a layer of finer masonry sand at the surface.

Compared to granular materials typically specified for routine construction projects in Wisconsin, it would be somewhat finer and with less of a coarse fraction and it may be somewhat rare to find this material as a natural bank. Within the Fox Valley, a variety of sand products are produced, and include both natural "bank run" material and "manufactured" material (from the crushing and processing of rock). As a result, a range of grain size distributions can generally be obtained, with correspondingly higher or lower amounts of coarse material and fines.

Cap materials for the Lower Fox River are assumed to be granular materials (sands, gravels, or stone) available from commercial sources. An initial inquiry into local sources indicates that at least one company is currently supplying a product that would meet the above specification at fairly low cost (e.g., less than $3 per cy, loaded but not delivered). In general, though, because this particular specification may routinely require a higher level of processing, an appropriate budgetary range, including transportation, may be in the range of $8 to $10 per ton.

A total organic carbon (TOC) content for cap material of 0.5 percent by weight will result in adequate binding capacity for hydrophobic contaminants such as PCBs (Palermo et al., 1998a). A minimum TOC concentration of 0.5 percent has been specified for a number of ongoing and proposed projects, and is considered appropriate for the Lower Fox River. Addition of TOC in the form of granulated carbon is anticipated to raise the sand cap TOC to 0.5 percent by dry weight.

## 3.2 CAP COMPONENTS AND THICKNESSES

For a major Superfund site such as the Lower Fox River, an appropriate level of conservatism should be considered in approaching the cap design. The total thickness of a cap and the composition of the cap components should be based on an evaluation of all the pertinent processes for the site and the ability of the design to achieve the intended functions of the cap. Processes that should be considered include physical isolation of benthic organisms, bioturbation, cap consolidation, erosion, operational factors, and chemical isolation. Some of the processes for design of cap components can be evaluated rigorously with models, etc., but others require engineering judgment. Cap design is evolving as more experience is gained across the range of project conditions. For cap design with a granular material, a conservative "layer approach" is recommended. As shown on Figure 3, each component is considered, and the necessary cap thickness is assumed as the sum of the layers for each component, with no dual function for the same cap component. For an armored cap with the surface layer composed of gravel or stone, the erosion protection layer may also act effectively as the bioturbation component, so a dual function is acceptably conservative for that layer. The following sections discuss considerations for the Lower Fox River, following the design flowchart on Figure 3 for evaluating and selecting the design of each of the cap components.

### 3.2.1 Determine Cap Design Objective

Cap design criteria were discussed in Section 1.4.2.

### 3.2.2 Bioturbation Component

Aquatic organisms that live in or on bottom sediment can greatly increase the migration of sediment contaminants through bioturbation. The depth to which species will burrow is dependent on the species' behavior and the characteristics of the substrate (e.g., grain size, compaction, and organic content). In general, the depth of bioturbation by marine organisms is greater than that of freshwater organisms. The types of organisms likely to colonize a capped site and the normal behavior of these organisms is generally well known. The technical report, *Subaqueous Cap Design: Selection of Bioturbation Profiles, Depths and Process Rates* (Clarke and Palermo, 2001), in addition to providing information on designing ISCs, also provides many useful references on bioturbation. The USACE has published this document on their website at: http://www.wes.army.mil/el/dots/doer/technote.html.

To provide long-term protection, an isolation cap should be sufficiently thick to prevent direct contact of burrowing organisms with the underlying contaminated sediment, or potentially contaminated subsurface layers of the cap. To design a cap component for this function, the bioturbation potential of local bottom-dwelling organisms should be evaluated. The Lower Fox River is a freshwater system, and the potential depths of bioturbation are limited to the upper few centimeters.

At marine and estuarine cap sites, the bioturbation component of the cap was the primary consideration. At both the Simpson Tacoma cap and the cap at the Convair Lagoon in San Diego, chemical isolation was achieved with a 12- to 18-inch layer of fine sand. The overall design and thickness of the cap was driven by the need to prevent deep-burrowing crustaceans from breaching the cap/sediment interface. At the Simpson cap, this was achieved by a layer of sand with an average thickness of 7 feet. The ISC constructed at Convair Lagoon in San Diego Bay included a gravel layer to resist potential bioturbation by deep-borrowing shrimp known to inhabit the site.

Knowledge of the local conditions and the species likely to colonize the cap is an important consideration in cap design. Deep-burrowing organisms are not likely to be a consideration at the Lower Fox River. A survey of noted aquatic biologists from several research facilities around the Great Lakes was conducted for the EPA ISC guidance document (Palermo et al., 1998b). The surveyed researchers generally agreed that the most likely benthic organisms to colonize a sand cap in the Great Lakes would be chironomids (midges) and oligochaetes (worms). One researcher indicated that spaerids (fingernail clams), trichopteran larvae, and nematodes might also colonize the sand cap. An armored cap would attract a greater diversity of macroinvertebrates than a sand cap, including those that attach to surfaces (including zebra mussels) or inhabit the larger interstitial spaces. As the interstices of the gravel or stone are filled with "new" sediments, the benthos would likely become dominated by oligochaetes and chironomids. Based on these opinions, a minimal component (or thickness) of an ISC constructed with sand or one having an armored surface appears to be needed to accommodate bioturbation at Great Lakes sites. Benthos at such a capped site is likely to be limited to the fine-grained, organic-rich sediments, which may deposit on top of the cap or settle in the interstices of armor stone. The armor layer component of the cap can therefore be considered the component for both physical isolation and bioturbation (see additional discussion below).

### 3.2.3 Consolidation Component

Fine-grained granular capping materials could undergo consolidation due to self weight. Even if the cap material is not compressible, most contaminated sediment is highly compressible, and will almost always undergo consolidation due to the added weight of capping material or armor stone. Therefore, consolidation must be considered when designing the cap. The thickness of granular cap material should have an allowance for consolidation so that the minimum required cap thickness is maintained following consolidation. Since the cap for the Lower Fox River would be constructed using sand and gravel/stone, evaluation of cap internal consolidation is necessary. The analysis of consolidation of the underlying contaminated sediments must also be conducted as a part of the evaluation of the chemical isolation cap component (see discussion below).

Consolidation of the underlying contaminated sediment will be a factor for the Lower Fox River. The degree of consolidation of the underlying contaminated sediment will provide an indication of the volume of water expelled by the contaminated layer and capping layer due to consolidation. This can be used to estimate the movement of a front of pore water upward into the cap. Such an estimate of the consolidation-driven advection of pore water should be considered in the evaluation of contaminant flux. Methods used to define and quantify consolidation characteristics of sediment and capping materials, such as standard laboratory tests and computerized models, are available (Palermo et al., 1998a, 1998b).

### 3.2.4 Stabilization/Erosion Protection Component

The cap component for stabilization/erosion protection has a dual function. This component of the cap is intended to stabilize the contaminated sediment being capped, and prevent the sediment from being resuspended and transported off site. The other function of this component is to make the cap itself resistant to external and internal erosion.

#### *External Stability*

The potential for erosion depends on stream flow or tidal velocity forces, ice scour, depth, turbulence, wave-induced currents, ship/vessel drafts, engine and propeller types, maneuvering patterns, sediment particle size, and sediment cohesion. Potential for episodic events such as floods, lake storms, ice dams, ship groundings, etc., should be evaluated. For the Lower Fox River, the potential for erosion due to floods is the major consideration for cap design. Ice scour is of concern only for water depths shallower than 3 feet, and habitat constraints and ice scour dictate that the surface of any cap on the Lower Fox River will not be at water depths less than 3 feet. Maintaining a minimum of 3 feet of water depth will also discourage establishment of emergent vegetation which might bioturbate the cap and exacerbate ice scour.

Hydrodynamic modeling conducted to date for the Lower Fox River has indicated that the surface cap layer must be designed as an armor layer to resist erosion. A detailed analysis of the armor layer requirements must be conducted as a part of the cap design. The analysis should be based on an evaluation of a 100-year flood event.

#### *Internal Stability*

Internal stability refers to geochemical processes that can create cap breaches. Little is known regarding the impact of gas generation on the effectiveness of a cap. Gas generation is a process related to internal geotechnical stability of the sediments, which has only recently received attention as a cap design consideration. Methane generation in sediments appears to be highly temperature-dependent (Matsumoto et al., 1992). The placement of a sand and gravel/stone cap may tend to isolate the fine-grained contaminated sediment layer from temperature changes, and could therefore reduce the potential for gas generation as compared to the uncapped existing conditions. Potential problems with gas generation that may affect cap design are gas buildup and contaminant migration associated with gas movement upward through the cap.

Gas generation and subsequent buildup may cause disruption of a membrane or low-permeability cap layer. This was illustrated by the displacement of a temporary membrane cap placed by EPA at the Manistique site. A 100-foot by 240-foot high-density polyethylene (HDPE) plastic membrane (40-mil) mat was placed over a hot spot at this site as a temporary control. The mat was weighted on the bottom with Jersey barrier concrete sections attached to the mat with cable and was fitted with 10 gas control valves to relieve gas buildup. An inspection of the mat 12 months after installation found that a number of bubbles had formed under the mat, causing upward displacement of the mat off the bottom as high as 8 feet (Lopata, 1994). Ultimately, this cap was removed and sediments were dredged from this site. In Wisconsin, a capping project at Oxbox Lake in Wausau capped lead-contaminated sediments in the late 1990s. The cap consisted of 2 feet of sand over a geotextile. A unique technical innovation on the project was that the cap materials were placed in the winter on the frozen lake surface and then allowed to settle into place upon ice melt. Results of a recent inspection report found that methane buildup under the geotextile caused part of the cap to surface, appearing as large bubbles at the water surface. This raising, in turn, pulled the geotextile and cap material off of the underlying contaminated sediments (WDNR, 2002c).

Since a granular material (sand) with no membrane or geotextile is anticipated for any Lower Fox River caps, there is no potential for a gas buildup problem, even if gas continues to be generated following cap placement.

Methane generation is common in most systems and has been observed at other capping sites, but has only recently become a consideration for cap design. For example, at one of the oldest and most successful caps, the Simpson-Tacoma site, methane seeps were observed coming out through the cap, and the Washington Department of Ecology required sampling to ensure that this breach did not carry contaminants (Stivers and Sullivan, 1994).

The models now in common use for evaluating cap effectiveness do not consider gas generation as a possible contaminant transport mechanism. As mentioned above, placement of a cap would insulate sediment from temperature increases during summer and would likely reduce the potential for gas generation. Based on these considerations, an increase in cap thickness to account for gas generation should be considered in determining an appropriate factor of safety in the cap design.

### 3.2.5 Chemical Isolation Component

If a cap has a properly designed physical isolation component, contaminant migration associated with the movement of sediment particles should be controlled. However, the movement of contaminants by advection (flow of pore water) upward into the cap is possible, while movement by molecular diffusion (across a concentration gradient) over long periods is inevitable. Since cap functions related to the quality of sediments in the cap are a goal for the Lower Fox River, an evaluation of contaminant flux and chemical isolation effectiveness of the cap is necessary. Such an analysis will include capping effectiveness testing and modeling.

Diffusion is the process whereby ionic and molecular species in water are transported by random molecular motion from an area associated with high concentrations to an adjacent area associated with a low concentration (Fetter, 1994). Although diffusion is a very slow process, diffusion-driven mass transport will always occur if concentration gradients are present. Consequently, diffusion can transport contaminants through a saturated porous media in the absence of advection. This process will be the principal mechanism for evaluation of cap design for the Lower Fox River from the standpoint of effectiveness for chemical isolation.

Advection refers to the flow of sediment pore water or underlying groundwater. Advection can occur as a result of compression or consolidation of the contaminated sediment layer or other layers of underlying sediment. Advection of pore water due to consolidation would be a finite, short-term phenomenon. Advection can also occur long-term as an essentially continuous process if there is an upward hydraulic gradient due to groundwater flow. Contaminants can be transported by advection as dissolved or particle-bound concentrations (e.g., ligand-sorbed colloids) (EPA, 1995). Available data indicate that continuous groundwater flow may not be a design issue for the Lower Fox River.[1] However, placement of the cap on compressible sediments will result in advection due to consolidation, and this process should be considered in the design.

Even if chemical concentrations are high in the contaminated sediment pore water, a granular cap component can act as both a filter and buffer to chemical migration during advection and diffusion, depending on the physical-chemical properties of the cap. As pore water migrates up into the uncontaminated granular cap material, these cap materials can be expected to fix or retard the transport of contaminants (through sorption, ion exchange, surface complexation, and redox-mediated flocculation) for some time. Therefore, pore water that traveled completely through the full thickness of the cap would theoretically have a reduced contaminant concentration until the filtering and/or buffering capacity or the cap is exhausted. The extent and duration of contaminant fixation or transport in the cap is very much dependent upon the nature of the cap materials. For example, a cap composed of quarry run sand would not be as effective as a naturally occurring sand with an associated fine fraction and organic carbon content.

Some components for cap thickness should not be considered in evaluating long-term flux. For example, the depth of overturning due to bioturbation can be assumed to be a totally mixed layer and will offer no resistance to long-term flux. Erosion components consisting of gravel or stone have little resistance to flux unless fine sediments fill the

[1] While groundwater inflow is not expected to be an issue, it will be necessary during cap design to confirm the absence of sand stringers underneath the cap foundation.

voids. Components for operational considerations, such as an added thickness to ensure uniform placement, would provide long-term resistance to flux. The void ratio or density of the cap layer after consolidation should be used in the flux assessment.

Several testing approaches have been applied to define cap thicknesses and the sediment parameters necessary to model their effectiveness in chemical isolation. Laboratory tests may be used to define sediment-specific and capping material-specific values of diffusion coefficients and partitioning coefficients. Although no standardized laboratory test or procedure has yet been developed to fully account for advective and diffusive processes and their interaction, both diffusion tests and batch and column tests for advective processes have been applied for cap designs. Such tests should be considered for the design phase for the Lower Fox River.

Several numerical models (both analytical and computer models) are available to predict long-term movement of contaminants into or through caps due to advection and diffusion processes. The results generated by such models include flux rates and sediment pore water concentrations as a function of time. These results can be compared to applicable water quality criteria, or interpreted in terms of a mass loss of contaminants as a function of time. The models can evaluate the effectiveness of varying thicknesses of granular cap materials with differing properties (grain size and TOC). The USACE has developed a comprehensive model called RECOVERY/CAP that allows consideration of a varying sediment profile and both advective and diffusive processes. Results from consolidation evaluations can be incorporated in RECOVERY/CAP to consider consolidation-induced advection. This model should be considered for evaluation of the chemical isolation effectiveness as a part of the cap design.

The performance standard of 250 ppb as a limiting PCB concentration in the isolation layer should be used in this analysis.

### 3.2.6 Operational Components

Even though cap placement methods are available which will minimize sediment resuspension and the mixing of cap material and softer contaminated sediments being capped, all placement methods will result in some degree of mixing. The degree of mixing will depend on the physical nature of the materials and the methods of placement. Mixing is an operational consideration that can be offset by increasing the overall cap design thickness. Penetration into soft, unconsolidated sediments of the initially applied sand cap was observed at the Soda Lake site in Wyoming. Up to 4 inches of the applied sand was found to have mixed with the softer, contaminated sediments before a solid foundation layer was formed that could bear the additional cap material. This is consistent with the modeled findings of Zeman et al. (1992) for the Hamilton Harbor site, who also cited work at the Hiroshima Bay, Japan ISC site where between 2 and 4 inches (5 to 10 cm) had mixed with the underlying contaminated sediments.

Another operational concern is the ability to place a relatively thin cap layer as a uniform layer. Various placement techniques have proven successful in placing layers about 15 to 20 cm (0.5 to 0.75 foot) thick with reasonable assurance (though at increased cost due to increased operational controls). The placement process will likely result in some unevenness of the cap thickness. This unevenness should be considered in calculation of the volume of capping material required.

An additional thickness of sand cap to account for operational considerations such as mixing and uniformity should be added to the design of the cap thickness (Palermo et al., 1998a).

### 3.2.7 Component Interactions and Overall Cap Thickness

The most conservative design approach for an ISC is to consider components necessary for the basic cap functions independently as described above. Using this approach, components are additive. This approach is most appropriate for caps designed with a single type of granular material, where the total thickness of cap material is the sum of the thicknesses for physical isolation, chemical isolation, and stabilization/erosion protection. Additional amounts of granular material might be added to account for consolidation (discussed below), or for other construction or operational considerations.

The cap components for physical isolation and erosion protection would seem to have the greatest potential for dual function. In the case of an armored layer placed on top of a sand cap and designed to be stable under all but very extreme events, the ability of such a layer as a deterrent to bioturbation might be considered in addition to its erosion protection function.

For the Lower Fox River, the cap design would require components for physical isolation/bioturbation, chemical isolation, and operational considerations. The total thickness of the sand cap layer and armor layer should be determined in the design phase.

For a major Superfund site such as the Lower Fox River, any cap design should incorporate an appropriate factor of safety applied to the cap thickness to account for uncertainty in site conditions, sediment properties, and migration processes. Based on professional judgment of the authors, a factor of 1.5 is considered appropriate. Regulatory or institutional considerations may favor a higher factor.

## 3.3 Geotechnical Considerations

Geotechnical considerations important to cap design include shear strength of the contaminated sediments (which determine their ability to support a cap), and liquefaction issues for seismically active areas. The Lower Fox River is not in a seismic risk area, so shear strength is the only geotechnical consideration.

Usually, contaminated fine-grained sediment is predominately saturated and therefore has low shear strengths. These materials are generally compressible. Unless appropriate controls are implemented, contaminated sediments can be easily displaced or resuspended during cap placement. Following placement, cap stability and settlement due to consolidation are two additional geotechnical issues.

As with any geotechnical problem of this nature, the shear strength of the underlying sediment will influence its resistance to localized bearing capacity or sliding failures, which could cause localized mixing of capping and contaminated materials. Cap stability immediately after placement is critical, before any excess pore water pressure due to the weight of the cap has dissipated. Usually, gradual placement of capping materials over a large area will reduce the potential for localized failures.

Field monitoring data have shown successful sand cap covering of contaminated sediment with low strength. However, data on the behavior of soft deposits during placement of capping materials is limited. Conventional geotechnical design approaches should therefore be applied with caution. These design approaches could be conservative for conditions normally encountered in cap design. For example, a cap should be built up gradually over the entire area to be capped. This will reduce the potential for mixing and overturning of the contaminated sediment. Similarly, caps with flat transition slopes at the edges should not be subject to a sliding failure normally evaluated by conventional slope stability analysis.

The capping material should be applied slowly and uniformly to avoid problems with bearing capacity or slope failures if the contaminated sediment deposit is soft. Uncontrolled release of a large amount of material or the buildup of a localized mound could cause a bearing capacity failure. If this occurs, cap material will penetrate into the contaminated deposit and could cause contaminated material to resuspend and disperse into the water column.

The sediments of the Lower Fox River are soft and compressible, but no more so than other sediments which have been successfully capped. Methods for cap placement should be considered to gradually build up the sand cap thickness and so minimize sediment and cap mixing and minimize potential for bearing type failures. Once the sand cap component is in place in a given working OU or area, the placement of armor stone can proceed using conventional placement methods.

## 3.4 CAP CONSTRUCTION

### 3.4.1 ISC Construction and Placement Methods

A variety of equipment types and placement methods have been used for capping projects. This has included the use of hopper barges at larger, open-water sites, and both hydraulic and mechanical systems for placement at nearshore or shallow-water sites. Some of these methods are shown and described on Figures 4 through 11.

The use of granular capping materials (sediment and soil), geosynthetic fabrics, and armored materials are all ISC considerations discussed in this section. Important considerations in selection of placement methods include the need for controlled, accurate placement of capping materials. Slow, uniform application that allows the capping material to accumulate in layers is often necessary to avoid displacement of or mixing with the underlying contaminated sediment. This can further result in the resuspension of contaminated material into the water column.

Granular cap material can be handled and placed in a number of ways. Mechanically dredged materials and soils excavated from an upland site or quarry have relatively little free water. These materials can be handled mechanically in a dry state until released into the water over the contaminated site. Mechanical methods (such as clamshells or release from a barge) shown on Figures 4 and 5 rely on gravitational settling of cap materials in the water column, and could be limited by operational depths in their application. Granular cap materials can also be entrained in a water slurry and carried to the contaminated site wet, where they are discharged into the water column at the surface or at depth (Figures 6 through 9). These hydraulic methods offer the potential for a more precise placement, although the energy required for slurry transport could require dissipation to prevent resuspension of contaminated sediment. Armor layer materials can be placed from barges or from the shoreline using conventional equipment, such as clamshells (Figure 10). Placement by mechanical buckets has also been successful at some sites (Figure 11).

### 3.4.2 Availability of Materials and Equipment

The local availability of sediment, soil, or other granular capping material can have a significant impact on ISC cost and implementation. Capping materials will generally represent the largest single item in the overall project cost. The selection of cap materials (or use of more than one) will be determined by the availability of materials that can meet the RAOs, their cost, and product quality control. Sources of granular materials should be carefully considered. Washed or processed sand would contain little or no organic carbon and would therefore not provide good contaminant isolation. As a result, the use of natural sandy sediment would be preferable for caps. Materials such as geotextiles or armor stone can generally be obtained from commercial sources.

## FIGURE 4 PLACEMENT OF THE ISC AT THE WEST EAGLE HARBOR OPERABLE UNIT, BAINBRIDGE ISLAND, WASHINGTON

**A**

**B**

**C**

Placement sand was obtained from routine navigation dredging in the Snohomish River, placed on a spilt-hull barge (A), which was then used to place most of the cap. In shallower areas, the weight of impact from the sand caused a displacement of creosote into the surface water. In order to achieve a softer placement of material, sand was placed on a flat barge and sprayed off the barge with a fire hose while the barge was pushed around the site by the tug (photos courtesy of USACE).

## FIGURE 5 HOPPER DREDGE PLACEMENT AT THE DENNY WAY COMBINED STORMWATER OVERFLOW

**A**

**B**

Sediments contaminated with metals, polynuclear aromatic hydrocarbons (PAHs), and PCBs below the Denny Way combined sewer overflow in Seattle, Washington were capped in conjunction with a source control program in the 1980s. Contaminated sediments were capped using a partially opened split-hull bottom-dump barge that was pushed laterally across the site. The cap consisted of approximately 5,000 cubic meters of uniformly graded sand (mean diameter 0.4 mm) spread to a thickness within a range of approximately 60 to 90 cm (Sumeri, 1991) (photos courtesy of USACE).

## FIGURE 6 HYDRAULIC PLACEMENT AT THE ST. PAUL WATERWAY, TACOMA, WASHINGTON CAP SITE

**A**

**B**

The dredged sand was piped to the site and discharged through a diffuser box that was fitted with baffles (A, B). The dredged material comprised approximately 85 to 95 percent medium sand, which included between 2 and 6 percent clays. Approximately 150,000 cubic meters of clean sand were spread over 6.9 hectares. The passes of the spreader barge included one-third overlap during placement to ensure adequate coverage. When completed, the cap ranged from between 0.6 and 3.7 meters in thickness (Sumeri, 1989) (photos courtesy of USACE).

## FIGURE 7 HYDRAULIC PLACEMENT AT SODA LAKE, WYOMING

A


B


C


D


E


F


The Soda Lake, Wyoming pilot project placed up to 3 feet of sand over very soft, unconsolidated refinery residuals mixed with sediments. A fine sand was mined on site (A), and conveyed (B) to a blending tank where they were mixed with water to form a 30 percent slurry by volume. The slurry was then pumped using two 175-horsepower centrifugal pumps in series through 4-inch pipe (D) to the spreader barge (E) where it was distributed using a 8-foot-wide diffuser box. The pipeline discharge entered the diffuser box spraying the slurry upward against a baffled surface. This surface distributed the slurry in a lateral fashion less than 1 foot above the water column and promoted a uniform material distribution. The capping material then hit the water column, lost its kinetic energy, and fell vertically onto the bottom sediment. The reduction in slurry velocity resulting from contact with the diffuser plate minimized any potential for erosion of in-place material. The selected sand layer (lift) applied was 1.5 inches per pass to minimize disturbance of bottom sediment and allow time for increased sediment pore pressures to equilibrate. Accumulating cap thickness was monitored during placement using both lead lines and a fathometer. In shallower areas, the cap was placed using an aerial disbursement method (F).

## FIGURE 8 DRY CAP PLACEMENT AT THE PINE STREET CANAL DEMONSTRATION PROJECT, VERMONT

A

B

C

A test capping project was undertaken at the Pine Street Canal Superfund Site in Burlington, Vermont. The site is located next to a former manufactured gas plant, where the Consent Decree calls for construction of an ISC in the canal to prevent exposure to aquatic life. The initial demonstration project placed up to 3 feet of sand using a dry-sand placement system mounted on a 16- by 40-foot barge with a shallow (2- to 3-foot) draft. A sand diffuser, consisting of a series of tremies, is attached to a feed hopper (A). A front-end loader is used to transport sand from the barge to the hopper. Sand from the hopper is distributed to the tubes via a rotating paddle located between the hopper and the tubes. This system, which is similar to that used at the Hamilton Harbor, Ontario capping site, uses a series of tremie tubes arrayed across an approximately 10-foot span (B). The barge is pulled along the installation path via a cable-and-pulley system (C). At this trial site, the diffuser was set to deliver either 0.5- or 0.75-foot lifts (photos courtesy of The Johnson Company).

## FIGURE 9 HYDRAULIC PLACEMENT OF CAP MATERIAL IN THE NETHERLANDS

This automated hydraulic capping barge has been developed in the Netherlands for the placement of thin layers of sand for capping of contaminated sediments or as a foundation layer on very soft sediments. The system, developed by the Dutch dredging firm Royal Boskalis Westminster, in alliance with Bean Environmental LLC of New Orleans, Louisiana, consists of a spreader barge connected to a slurry pump, which is loaded by either a dredge or hopper. The production of the solids is measured in real time. The winch system of the capping barge is a fully automated, dynamic tracking system and follows parallel lanes. The hauling speed of the barge is automatically steered by the quantity of capping material discharged, the lane width and the required layer thickness of the cap. The system was used in the construction of foundation layers at the Derde Merwede Haven and Ketelmeer confined disposal facilities, and for the placement of foundation layers at the Ijburg residential island construction in Amsterdam, where very thin layers of sand were required to be placed on an extremely soft surface sediment. All of these sites are located in the Netherlands. The automated capping barge achieves production rates in excess of 1,500 cubic meters per hour, and provides material distribution of clean, poorly graded imported sand in uniform 0.3- to 0.7-meter layer thickness by means of this sophisticated slurry control and barge advance system (photo courtesy of Bean Environmental LLC).

## FIGURE 10 MECHANICAL PLACEMENT AT THE SHEBOYGAN DEMONSTRATION PROJECT

A


B


C


The demonstration project at the Sheboygan River, Wisconsin, placed a composite cap over PCB-contaminated sediments. The project first set a 100-micron geotextile fabric placed directly over the soft sediments (A), followed by a 12-inch layer of run-of-bank material (B), a second geotextile fabric layer that was secured with 3-foot by 3-foot stone-filled gabions at the perimeter, and then finished with a 12-inch-thick armor layer of 4 to 12 inches of cobble (C).

## FIGURE 11 MECHANICAL PLACEMENT AT WARD COVE, ALASKA

**A**

**B**

Ward Cove near Ketchikan, Alaska was capped as part of a CERCLA action in 2000–2001. Contaminants at Ward Cove were byproducts of the paper waste product that was released during wastewater discharge. The EPA wanted to evaluate a thin-layer capping (6 inches) alternative as a method for enhancing natural recovery and as a habitat improvement action. The underlying material was very soft, unconsolidated sediment with low *in-situ* shear strength and high water content. Placement was with an 8.5-cubic-yard (cy) bucket that was welded to hold an exact amount of material that was equivalent to a 6-inch placement over the 300-square-foot arc across which the bucket was swung. The material was released below the water surface within 10 to 20 feet of the bottom. Sediment grain size for the cap was a fine to medium sand that was less than 5 percent non-plastic silt. The contract was written so that the contractor was paid by the amount of material placed. Gravity probes were used to confirm that the project was successful; a final cap thickness of 6 to 9 inches was achieved (photos courtesy of Greg Hartman).

### 3.4.3 Contaminant Releases During Construction

During cap placement, resuspension, volatilization, or other movement of chemical contaminants can occur. The potential short-term risk to the community, workers, or environment during cap placement should therefore be evaluated. Even though there are no standardized methods to predict the degree of contaminated sediment resuspension resulting from cap placement, field data provide some insight on this process. EPA has conducted monitoring of capping-induced resuspension for projects at Eagle Harbor and Boston Harbor (Magar et al., 2002). Capping resuspension was low for both of these sites and decreased as capping operations continued. Similar results were also found for capping resuspension monitored for a large-scale capping field pilot study at the Palos Verdes site (Palermo et al., 2001; McDowell et al., 2001), where contaminant concentrations quickly returned to background levels. Extensive water quality monitoring of capping-induced resuspension conducted for the Soda Lake project (ThermoRetec, 2001) found no detections of site-related petroleum hydrocarbons. The overall results from these studies indicate that levels of sediment resuspension due to well-managed capping operations were acceptable and comparable to those for well-managed environmental removal projects.

Measures to reduce the potential for resuspension, volatilization, or other contaminant movement should include selection of cap materials, placement equipment, and methods designed to spread the capping material over the site gradually. For the Eagle Harbor project, cap material was hydraulically washed off a barge. A manifold arrangement for placement of cap material slurry was used at a capping project at Hamilton Harbor in Canada. At both the Simpson Tacoma project and Soda Lake, a horizontal auger dredge was used as a cap material placement device. These and other projects illustrate the range of possible approaches that have been successfully used to place caps in a gradual manner to minimize potential for resuspension and displacement of contaminated sediments.

The potential short-term risk to the community, workers, or environment during cap placement should be evaluated. Measures to reduce the potential for resuspension, volatilization, or other contaminant movement should include selection of cap materials, placement equipment, and methods designed to spread the capping material over the site gradually. Selection of the proper construction techniques will allow the cap to be gradually built up without the potential for geotechnical instability (bearing or slope failure) or excessive disturbance. In addition, silt curtains and other barriers can be used to prevent or minimize contaminant migration. In extremely contaminated areas or at shallow sites, sheet pile cofferdams can be used to prevent contaminant migration from the construction site.

# 4 MONITORING CONSIDERATIONS

A monitoring program should be required as a part of any capping project design. The main objectives of monitoring for ISC would normally be to ensure that the cap is placed as intended and that the cap is performing the basic functions (physical isolation, sediment stabilization and chemical isolation) as required to meet the remedial objectives. Specific items or processes that may be monitored include cap integrity, thickness, and consolidation, the need for cap nourishment, benthic recolonization, and chemical migration potential.

Intensive monitoring is necessary at capping sites during and immediately after construction, followed by long-term monitoring at less frequent intervals. In all cases, the objectives of the monitoring effort and any management or additional remedial actions to be considered as a result of the monitoring should be clearly defined as a part of the overall project design. The cost and effort involved in long-term monitoring and potential management actions should be evaluated as part of the initial FS.

Monitoring programs for Simpson, Eagle Harbor, Soda Lake, and other projects have included components for resuspension and cap integrity during construction as well as components for long-term cap effectiveness. Plume monitoring with instruments as well as discrete samples for contaminant concentrations are the usual approaches for resuspension monitoring. Pre- and post-bathymetric surveys, along with consolidation measurements, help evaluate whether cap thickness design objectives are achieved. Cores taken through the cap are the most frequent tools used to determine cap integrity during and immediately following construction as well as at longer time intervals for purposes of long-term effectiveness. Samples from the cores are analyzed for both physical parameters as well as sediment and/or pore water chemistry.

For the Lower Fox River, it is especially important that the performance standard of 0.25 ppm in the upper layer of the cap be confirmed by monitoring.

Any construction monitoring to determine if this standard is met needs to occur PRIOR to placement of the armor layer. For long-term monitoring for effectiveness, sediment samples should be taken in the lower portions of the cap profile in addition to the upper biologically active zone. This will determine if any contamination in the cap is due to cap performance issues (migration from below) or recontamination from above.

# 5 INSTITUTIONAL AND REGULATORY CONSIDERATIONS

There are very few federal or state laws that pertain specifically to ISCs. While various chapters of the Wisconsin Administrative Code contain technical or administrative requirements for the management of waste material and contaminated media, there are no regulations that are specifically directed to the planning, permitting, design, construction, or maintenance of ISCs.

On the other hand, there are certain compelling interests in managing contaminated sediment that are parallel to those that arise when managing wastes and contaminated media. In a certain sense, a sediment cap, as a means of protecting human health and the environment, is analogous to a landfill cover at a Subtitle D facility or a soil performance standard at a spill site. Like these other control mechanisms, a cap over contaminated sediment can reduce the likelihood of migration, the opportunity for contact and biological uptake, or a combination of both. As with some land-based containment systems, the sediment cap uses earthen materials to provide control and physical separation. When correctly designed, properly constructed and well maintained, it can be an alternative method for achieving risk-based goals for reducing human and aquatic exposures.

A soil, aggregate, or multimedia cap that is used to contain contaminated sediment might therefore be subject to the same kinds of objectives as for other regulated materials. These include the following:

- The selection of the type of cap should be based on providing an appropriate physical barrier to limit contact with or migration of contaminants (or both).
- The design of the cap should provide for resistance to erosion, decay, or incidental penetration.
- The cap should be subject to periodic inspections and maintenance to insure that it accomplishes its design objectives over its intended life.
- Financial assurance should be established to provide for this post-construction, long-term monitoring, and maintenance.
- The cap must meet the substantive requirements of both state and federal law.
- The planning, design, construction, and monitoring phase of the project should be subject to state review at certain key milestones.

The fulfillment of objectives like these is the basis for various state regulations. Certain rules provide specific technical requirements for environmental facilities (e.g. solid waste landfills, hazardous waste incinerators, wastewater treatment plants). Other rules require the use of general evaluation methods and broad mandates for accomplishing protection (e.g., the NR 700 series of rules for remedial actions).

In addition, since the use of an ISC involves construction within navigable waters, there are additional considerations beyond those that affect land-based remediation. These are discussed specifically in the following subsection. Federal rules, other state rules, institutional considerations, and recent practices are discussed in subsequent subsections.

## 5.1 CONSTRUCTION WITHIN NAVIGABLE WATERS OF WISCONSIN

Wisconsin Statutes Chapter 30 prohibits the deposition of materials except into structures that are permitted or authorized under statute or other legislative means (WDNR, 1998). It also requires the issuance of permits for the construction of any structure on the bed of navigable water. The authorization and permitting of a project is, in turn, affected by the ownership of the bed. In Wisconsin, this varies according to the type of water body, as follows:

- For natural, navigable lakes the state owns the bed.
- For rivers, upland owners have riparian rights that extend to the center of the stream. (This includes "man-made" lakes or reservoirs created by the damming of a river. Riparian ownership is determined as though the previous stream still remains.)

As a result of these differences, deposits on the bed of navigable waters have historically been authorized under by one of four means (WDNR, 1998):

1. **Legislative Authorization:** For a river, the legislature can authorize a project with riparian owners as applicants or co-applicants. (In this context, it is important to note that riparian owners may separate the ownership or the riverbed from the ownership of the adjacent land, and riparian rights may be sold or leased.) In doing so, however, the project must be shown to be consistent with the public trust doctrine.

2. **Lakebed Grants:** For lakes, a "lakebed grant" from the legislature can remove the prohibition on deposits of material. The structure itself would still be subject to all approvals and permits required to protect the water quality of the surrounding water body.

3. **Bulkhead Lines:** Bulkhead lines can be used, but are required to conform as nearly as practicable to existing shores. Therefore, they would probably not be applicable to a broad area of ISC placement.

4. **Leases:** The Commission of Public Lands may lease the rights to the beds of lakes to a municipality for the purpose of improving navigation or harbors. The WDNR must establish that such a lease would be in the public interest, and they may include conditions of use and operation.

These considerations indicate that an RP who wishes to construct a sediment cap is not free to do so without consideration of riparian rights and without a means of authorization from the State. From the outset, there would be a commercial aspect to this process, in that the RP may need to negotiate with and provide compensation to private riparian owners. Equally important, however, would be the demonstration that the proposed ISC is an improvement allowable and envisioned under state law and that if authorization is provided, the state would continue to maintain its obligation to the public trust. Further, once the appropriate means of authorizing the project is established and implemented, the regulatory permitting process will add requirements that are necessary for the protection of the aquatic resource.

The applicability of Chapter 30 requirements and the use of lakebed grants for sediment caps is just beginning to be explored. While the WDNR has started to make determinations on which authorities (e.g., legislative authorization, lakebed grants, etc.) might be used on certain water bodies, it does not appear that a sediment capping project has yet moved fully through the process. Final determinations are likely to require considerable additional work and subsequent interpretations. In addition, obtaining a lease or lakebed grant is likely to result in additional financial encumbrances not otherwise accounted for.

## 5.2 OTHER WISCONSIN REGULATIONS

Beyond the laws that specifically affect the ability to construct a project within navigable waters, there are a range of other possible state regulations that may affect the planning, design, construction, or maintenance of an ISC remedy. Table 4 contains information on state regulatory requirements. These regulations, which cover such things as capping of upland disposal sites and other aspects of remedial activities, are not directly applicable to an ISC. They do, however, provide some general direction and they suggest how relevant state regulations may be considered for an ISC project.

Each of these items is characterized (for informational purposes) as being either "procedural" or "technical." A procedural item, for example, could be the submittal of a work plan or other document. A "technical" requirement might specify a design feature, material of construction, or construction method.

The "procedural" aspects of the NR 700 series would probably be relevant to most ISC projects because they are, by definition, intended to be generic to a wide range of remedies. Technical items developed under other regulatory programs may have less relevance because they are usually facility-specific (such as the thickness of the vegetative layer for a landfill cover).

## 5.3 FEDERAL REQUIREMENTS

Section 10 of the Rivers and Harbors Act of 1899 (22 CFR 403) permitting is required for any construction that would impact the course, capacity, or condition of navigable waters of the United States (Palermo et al., 1998b). Any cap would be considered as an obstruction to navigation. For the Lower Fox River, the federal navigation channel runs the length of the River up to the Menasha Locks to Lake Winnebago. If a cap footprint were proposed within an authorized federal navigation channel, congressional action would be required to de-authorize the project or modify the authority.

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| ***Chapter NR 504 – Landfill Location, Performance, Design, and Construction Criteria*** | | | | |
| 504.07 | Technical | This paragraph establishes minimum design requirements for a solid waste landfill cover system. Includes design objectives, materials specifications, and thickness of layers. | Yes. The sediment cap is analogous to a landfill cover. It is subject to some of the same kinds of stability and long-term maintenance concerns which have been addressed for landfill covers via this paragraph. | The NR 500 series of regulations are not applicable to sediment capping. Further, the specific design elements contained in this paragraph are not relevant to a sediment cap. However, some of the underlying design objectives for landfill covers that are stated in 504.07(1)(a) would be relevant and appropriate. These include:<br>• "Reduce…maintenance by stabilizing the final surface…" and<br>• "Account for differential settlement and other stresses on the capping layer…"<br><br>Just like in a landfill cover project, these objectives would form the basis for design of the sediment cap (i.e., the selection of materials and thickness that would resist erosive forces in the River and which could be adequately supported by the sediment bed). |
| ***Chapter NR 506 – Landfill Operational Criteria*** | | | | |
| 506.08 | Procedural and Technical | Establishes general closure requirements for solid waste landfills, as well as specific requirements for facilities that accepted municipal solid waste up to certain cutoff dates. | Yes. The sediment cap could be viewed as the closure mechanism for a historic disposal location. | Not applicable. Because they are focused on a particular kind of solid waste facility, the specific content of this paragraph is not as relevant to a sediment cap as other parts of the NR 500 code might be. |

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| ***Chapter NR 514 – Plan of Operation and Closure Plan for Landfills*** | | | | |
| 514.08 | Procedural | Requires the submittal of a closure plan for solid waste disposal facilities that do not have an approved plan of operation, or which are required to develop a closure plan as remediation for surface water contamination. | Yes. The sediment cap is, in part, a response action to an instance of surface water contamination. | Appears relevant. Because it is only a procedural requirement, though, it may not be appropriate if another relevant regulation is invoked (such as NR 724.09, 724.11, or 724.13) that requires equivalent information in a more focused document. |
| ***Chapter NR 516 – Landfill Construction Documentation*** | | | | |
| 516.04 | Procedural | Describes the procedures for construction quality assurance and documentation reporting for construction at solid waste landfills. | Yes. The construction of the sediment cap is analogous to the construction of a landfill cover and would be subject to the same kinds of construction quality assurance and documentation. | Appears relevant. This paragraph merely sets forth a procedural task that is already largely consistent with conventional engineering practice. It would only be viewed as not appropriate if some other relevant regulation is invoked (such as NR 724.15) which is more targeted to remediation work. |
| 516.06 | Procedural and Technical | This paragraph describes more of the substantive requirements for closure documentation and reporting, such as the grid interval for determining final grades and the content of documentation drawings. | Yes. The types of documentation activities anticipated by this paragraph would also occur in a sediment capping project. | Some of the general requirements would be relevant. It would only be viewed as not appropriate if some other relevant regulation is invoked (such as NR 724.15) which is more targeted to remediation work. |

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| 516.07 | Technical | Contains the required frequency for materials testing during construction. | Yes. Some of the earthen materials used in a landfill cover may also be used in a sediment cap. | Some of the requirements for testing of specific materials (such as sand or small aggregate) may be relevant and appropriate. (Note that as a practical matter and so that the total number of samples is not unreasonable, the actual frequency of testing may be modified if very large volumes of cap material are required.) |
| ***Chapter NR 520 – Solid Waste Management Fees and Financial Responsibility Requirements*** | | | | |
| 520.05 | Procedural | This paragraph identifies three types of site activity for which owners of solid waste facilities must establish financial responsibility:<br>• Closure;<br>• Long-term care; and<br>• Remedial action. | Yes. Construction of a sediment cap constitutes a closure action, and long-term care (maintenance) is necessary. | Although a sediment cap is not one of the specific facilities identified in NR 520, the objective of establishing responsibility for future costs is relevant. |
| 520.06 | Procedural | This paragraph identifies seven different financial instruments by which owners can establish financial responsibility. | | |
| 520.07 and 520.08 | Technical | Identifies the types of costs and methods of estimating which must be included within the categories of closure, long-term care and remedial action. | | |

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| ***Chapter NR720 – Soil Cleanup Standards*** | | | | |
| **Note:** The elements within this chapter that describe the process for calculating soil cleanup standards are not included in this analysis. For the Lower Fox River and Green Bay, the action level for contaminated sediments would be based on site-specific risk calculations and risk management decision. | | | | |
| 720.19(2) | Technical | Allows for the use of a soil performance standard when contaminants are left in place (in excess of what would otherwise be a residual contaminant level). If used, the soil performance standard must then be operated and maintained in accordance with NR 722 and NR 724 (see below). | Yes. A "soil performance standard" may consist of an engineering control, such as a physical barrier, to limit exposure or contact with residual contaminants. In this sense, a sediment cap is analogous to a cover system, pavement or other containment structure. | May be relevant. The rule anticipates that a soil performance standard would achieve one of more of the following:<br><br>1. Isolate residual contaminants from direct contact (by a physical barrier);<br>2. Limit infiltration and subsequent migration via groundwater (via a low-permeability barrier); or<br>3. Otherwise stabilize the soil while natural degradation reduces the contaminant concentration to within acceptable levels.<br><br>Goals Nos. 1 and 3, for example, could be similar to those sought when selecting a sediment cap as a remedy. |
| ***Chapter NR 722 – Standards for Selecting Remedial Action*** | | | | |
| 722.09(2)(c)(3) | Procedural | This paragraph requires that, for sites "in surface water bodies or wetlands," active remedial actions be taken to preclude any exceedance of water quality criteria in Chapters NR 102 to NR 106. | Yes. In some cases, the goal of the sediment cap may be to prevent resuspension or dissolution of contaminants that might lead to an exceedance of water quality criteria in the overlying water column. | Could be relevant to the evaluation and selection of a sediment cap. |

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| 722.09(3) | Procedural | This paragraph introduces the concept of a performance-based standard in lieu of a numeric cleanup standard. | Yes. A sediment cap is a "performance-based" remedial action (as compared to, say, an action that removes contaminants down to a risk-based, numeric standard). | Appears relevant. |
| 722.13 | Procedural | This paragraph contains the requirements for the submittal of a Remedial Action Options Report (RAOR). | Yes. Presumably, the selection of a sediment cap would generally be made after a review of remedial options and that process would generally be documented in a report of this type. | Appears relevant, unless the project is organized under some other regulatory authority (such as CERCLA) with its own document submittal requirements. The analog to a ROAR would probably be an FS. |
| ***Chapter NR 724 – Remedial and Interim Action, Design, Implementation, Operation, Maintenance and Monitoring Requirements*** | | | | |
| 724.09 | Procedural | Describes the required contents for a "design report" for the selected remedial action at sites regulated under Section 292.11 or 292.31. (This also applies to sites referenced in 724.02, which in turn specifically includes "on-site engineering controls or barriers…") | Yes. Such a report would most likely be produced for any capping project once the concept for the remedy was established and approved. | NR 724 appears relevant because of the broad definition of regulated sites and the latitude that WDNR has in selecting a regulatory authority (NR 724.02(2)). The regulation sets forth a procedural task that is already largely consistent with good and conventional engineering practice. On the other hand, the regulation may not be appropriate if the site is being managed under the NCP where the administrative requirements for document submittal are generally more comprehensive. |

## TABLE 4 WISCONSIN "ACTION-SPECIFIC" REGULATIONS THAT MAY BE RELEVANT TO SEDIMENT CAPPING PROJECTS

| Citation from Wisconsin Administrative Code | Is the Regulation Procedural or Technical? | Specific Item | Is There a Parallel Procedural or Technical Element in a Sediment Capping Project? | Comment |
|---|---|---|---|---|
| 724.11 | Procedural | Includes the substantive requirements for the production and submittal of construction-level plans (drawings) and specifications. | Yes. These documents would routinely be produced prior to construction of the project. | Appears relevant. The regulation sets forth a procedural task that is already largely consistent with conventional engineering practice. May also be appropriate if more comprehensive NCP protocols are not being followed. |
| 724.13, especially (2) | Procedural | Includes the substantive requirements for the production and submittal of an "operation and maintenance plan." It includes the consideration of long-term monitoring, required under 724.17 (see below). | Yes. Such a plan could also be produced to describe the post-construction inspection, testing, and maintenance of the cap. | |
| 724.15 | Procedural | Includes the substantive requirements for the production and submittal of a "construction documentation report." | Yes. This kind of report would routinely be produced to document the construction of the cap. | |
| 724.17 | Procedural | Includes the substantive requirements for the parameters, frequency, and reporting of a long-term monitoring program. This paragraph also allows for a 5-year review by WDNR. | Perhaps. Such a program would be an element of the operation and maintenance plan. In addition to monitoring of the physical nature of the cap, it might also incorporate ongoing sediment chemical monitoring if long-term natural degradation of contaminants is an expectation of the remedy. | Parts of the paragraph appear relevant. Certain elements which anticipate chemical monitoring and data reporting may not be relevant. May also be appropriate if more comprehensive NCP protocols are not being followed. |

While daunting, such relief from federal requirements is not unachievable. For example, capping was conducted on a portion of the federal navigation channel at the Manistique Harbor Superfund site in Michigan. That action was approved in Congress. For the Lower Fox River, Congress has approved the transfer of authority for the existing system of locks from the USACE to the state. In this case, the federal government will also relinquish control of the channel. In turn, the state has indicated that it will maintain a navigational depth of at least 4 feet. (Note that, while authorized, this transfer has not yet occurred.) If this is accomplished, a grant or release will then be required from the State Legislature. Until that time, however, the state's current interpretation is that "you can't fill in a federal channel."

## 5.4 INSTITUTIONAL CONTROLS

In addition to the affects of specific state and federal laws and regulations, a series of institutional considerations will also affect an ISC project. These may include restrictions on the bed where the project is constructed (analogous to traditional "deed restrictions" for a land-based project), as well as possible "water use" restrictions that would affect the resource overlying the bed.

Whether a cap is constructed over a leased bed from a riparian owner, or as part of a lakebed grant by the legislature, it will be necessary to set permanent restrictions on future development. This may include restrictions on setting utility or cable corridors, construction of fixed-post docks, or any other construction activity that would otherwise disturb the integrity of the cap. Water use restrictions might include limits on anchoring or propeller and keel impacts.

An assessment of the need for and reliability of such institutional controls should be part of an evaluation of the long-term effectiveness and permanence of a capping remedy. The ability to devise appropriate controls, educate the public regarding the need for controls, and enforce the controls should also be considered.

An inherent assumption in the cap designs discussed herein is that the location of the ISC will remain permanently submerged. On the Lower Fox River, this in turn, requires a commitment to the maintenance of the system of dams and locks on the River. There are already a number of compelling reasons for doing so (such as providing a lamprey barrier, hydropower capability, water supplies, and recreational use), but the use of ISC as a long-term remedial action will add to this list.

This range of institutional controls should be identified and memorialized as part of a detailed, long-term maintenance plan (LTMP). More broadly, the LTMP would include such elements as the following:

- Identification of failure modes that could result from the loss of institutional controls (degradation from propeller wash, etc.);

- Identification of failure modes the could result from natural causes (excessive ice scour, extreme flood events, etc.);

- Description of maintenance procedures or restoration activities needed for each type of failure;

- A schedule of routine inspections and sampling; and

- A means of identifying if the ISC has been affected by contaminants reloading the River system.

When routine inspections and sampling indicate a potential problem, actions will be required to physically repair the cap. A more complete assessment will be required to fully evaluate the type and severity of the failure and potential corrective measures. There are several ways a cap may fail. The more benign would be contaminant flux is greater than estimated and the design concentration has been exceeded. Catastrophic failure could occur during placement (due to shear failure) or scouring due to flood, ice, or propeller wash. Once this is determined, the type of maintenance can be specified. Maintenance could range from full cap replacement to placing additional cap materials or armor over the failed area.

## 5.5 FIDUCIARY RESPONSIBILITY

Fiduciary responsibilities for an ISC are equivalent to those associated with any upland landfill or soil cap; the RP retains the long-term liability for the cap in perpetuity. This is also consistent with soil caps at brownfield sites, where there is no transfer of liability for the site. An additional fiduciary responsibility that will need to be considered for an ISC at the Lower Fox River includes the long-term maintenance of dams on the River, and/or the potential for management of remnant deposits in the event of dam failure or removal.

## 5.6 RECENT PROJECTS WITHIN WISCONSIN

This section describes how ISC projects have been approved, designed, and/or implemented in Wisconsin. Where appropriate, references are made to some of the regulations described above.

While there have been a large number of capping projects addressing soils and waste materials within the state, only a very limited number of ISCs have been built. Two examples include the Sheboygan River and Harbor, a National Priorities List (NPL) site in eastern Wisconsin, and the Wausau Steel site, in north central Wisconsin.

At Sheboygan, PCBs were (and are) the constituent of concern. Sediment “armoring” was proposed as a pilot study in approximately 1989 and constructed in 1990, as part of the Alternative-Specific Remedial Investigation (ASRI) for the site. The objectives of the pilot study were as follows (Blasland, 1989):

- Demonstrate the constructability of the technology;
- Evaluate the effectiveness of reducing water column PCBs;
- Evaluate the effectiveness of reducing the bioaccumulation potential of PCBs;
- Develop engineering data for future projects; and
- Assess the impact on in-situ biodegradation of PCBs.

From an engineering perspective, the Sheboygan cap was designed for structural integrity. It is not clear how the above-stated goals impacted the specific design chosen. In total, it consisted of the following layers and materials:

- Geotextile fabric (placed directly on the soft sediments);
- 6-inch minimum run-of-bank aggregate material;
- Geotextile fabric;
- 6 inches of cobble; and
- The perimeter of the geotextiles was anchored with 3-foot by 3-foot stone-filled gabions.

The Sheboygan River project has followed federal National Contingency Plan (NCP) protocols. Both EPA and WDNR provided review of and comments on the technical aspects of the work. The project pre-dated the Wisconsin NR 700 series of rules and there were no specific technical regulations available or cited that covered the planning, design, construction, or operations of the sediment cap. WDNR commented at the time that, in general, the technology should be used sparingly and only for sediments at point bar locations with "low" PCB concentrations (WDNR, 1989). Specific contaminant levels were not stated.

Since it was constructed as a pilot project, the burden of performance monitoring would have fallen on the RP. Apparently, an agreement with the RP on a suitable monitoring program was never reached (Janisch, 2002). As a result, there appears to have been only limited monitoring or studies targeted towards determining the success with which the above-stated goals have been met. In a general sense, the performance has not been viewed favorably. Deficiencies observed by WDNR personnel over time have included the following (Weitland, 2002):

- From a biological standpoint, the technology was felt to be inappropriate.
- PCB concentrations in downstream sediment traps increased (although it is not certain that these PCBs emanate from the armored locations).
- There has been visible damage to the gabions resulting from subsequent storm events and/or ice action.

As early as 1997, after a technical review of the original FS for the permanent site remedy, the Lake Michigan Federation recommended that the removal of the armoring be included as a component of some of the long-term alternatives for the site (BT2, 1997). In fact, EPA's Record of Decision for the final site remedy now calls for it to be removed.

A second sediment capping project of interest has been the Wausau Steel project in Wausau (also referred to as the "Oxbow Lake" site on the Big Rib River). The contaminants of concern were zinc and lead, and a cap was proposed in the late 1990s as a means of addressing both in-place sediments and on-site soils. The Remediation and Redevelopment Bureau and the department's sediment team jointly reviewed the project. Chapter 30 permitting (referenced above) was administered through the department's Water Regulation and Zoning group, as for any construction in a navigable waterway.

The cap consisted of 2 feet of sand over a geotextile. The technical innovation on the project was that the cap materials were placed in the winter on the frozen lake surface and then allowed to settle into place upon ice melt.

The RP, through a consent order, is required to perform monitoring and maintenance for a 5-year period and to submit annual reports. To date, much of the cap has survived. However, within the first few years following construction, WDNR personnel observed that, in places, tears and holes had occurred, and some of it was pulling away from the shoreline. Erosion has occurred from storm events, and in at least two areas, gas generation from beneath the geotextile has caused it to "bubble." It had pushed through the sand layer and was exposed above the water's surface.

Maintenance has included the placement of additional sand, as needed. Nonetheless, these conditions have led the WDNR to raise questions that affect not only this project, but that will most likely be relevant in evaluating the design or implementability of future ISCs. These issues include the following (Janisch, 2002):

- In light of these initial observations (which to date affect only relatively small areas), what are the implications for long-term stability and effectiveness?
- Will water levels or ice action cause additional damage or worsen the existing defects?
- What is an appropriate degree of monitoring and maintenance over the long term?

While the RP has met the state's requirements to date, the WDNR does not currently have a mechanism in place for maintenance over the longer term. With this experience, department staff now recognize that some kind of extended monitoring or financial assurance may be needed as conditions of future orders.

For caps over contaminated soil and waste material, the WDNR has used both the NR 700 and NR 500 series of regulations as appropriate. Some specific examples include the following:

- When direct contact is the exposure pathway, the remedy selection process within NR 726 has resulted in the use of soil caps consisting of 1 to 2 feet of clean soil. (Note that a direct contact pathway for unsaturated soil would be analogous to an aquatic uptake pathway for sediment. The remedial objective of isolating the material is met by providing a layer of material of designated thickness.)

- When waste material has been excavated and relocated or consolidated, a cover designed according to the NR 500 rules has been required. Depending on the nature of the material, it may also be underlain by a liner designed according to NR 500 requirements. (In at least one innovative application, the NR 500 liner design was modified to add a layer or chemically reactive material suitable for neutralizing an acidic leachate.)

- When deed restrictions are needed on the capped property, NR 726 is used.

When long-term maintenance or monitoring is necessary, NR 700 has been invoked. The cases noted have generally involved larger, financially stable RPs, and financial responsibility has not been questioned. The issue of using NR 500 financial assurance requirements as a relevant and appropriate requirement for an NR 700 maintenance activity has apparently not yet been explored. In this regard, it is interesting to note that as early as 1999, a review of the Sheboygan remedy completed on behalf of the Lake Michigan Federation pointed to the need for an escrow account to cover the costs of long-term impacts when impacted sediments are left in place (BT2, 1999).

# 6 COST ESTIMATES

The cost of capping projects will be largely dependent on the thickness of the cap, cost of capping materials, and associated transportation and placement costs. However, monitoring costs can be significant when long-term needs are considered. Some example projects are discussed below.

The Simpson Cap was part of a 1988 cleanup of the St. Paul Waterway (part of the Commencement Bay Nearshore/Tideflats Superfund site in Tacoma, Washington). The PRPs dredged clean sediment from the nearby Puyallup River to cap dioxin-contaminated sediments with a 17-acre, 4- to 20-foot-thick cap, at a cost of $5 million, or about $290,000 per acre. The cap had two purposes: to isolate the contaminated sediment and to raise the bottom elevation to create a new intertidal habitat. Estimated long-term monitoring costs were $3 million for the first 10 years of monitoring.

The East Operable Unit of the Eagle Harbor Superfund Site at Bainbridge Island, Washington was constructed in 1994. At this site, the EPA and USACE placed a 50-acre, 3-foot-thick cap over PAH-contaminated sediments. Construction costs were reduced by using clean dredged materials from routine maintenance dredging of the Snohomish River for the cap. The construction cost for this project was $2 million and monitoring costs are approximately $125,000 per year.

The Soda Lake cap was part of a technical feasibility analysis for capping of RCRA refinery residuals at a settling pond located near Casper, Wyoming. Sand was mined on site at a cost of ca. $6.50 per ton, and then placed over a 5.7-acre site to a construction depth of 3 feet, with a 20:1 side slope yielding a total footprint of 7 acres. The base sediments were highly unconsolidated, and thus capping over the main body of the site occurred in 1.5- to 3-inch lifts to allow for slow consolidation and dissipation of accumulated pore pressures to prevent load failure. The cost for construction was approximately $600,000, with an approximate monitoring cost of $250,000 for placement and post-placement monitoring.

Ward Cover near Ketchikan, Alaska was capped as part of a CERCLA action in 2000–2001. Contaminants at Ward Cove were byproducts of the paper waste product that was released during wastewater discharge. The EPA wanted to evaluate a thin-layer capping (6 inches) alternative as a method for enhancing natural recovery and as a habitat improvement action. The underlying material was very soft, unconsolidated sediment with low *in-situ* shear strength and high water content. Placement was with an 8.5-cubic-yard (cy) bucket that was welded to hold an exact amount of material that was equivalent to a 6-inch placement over the 300-square-foot arc across which the bucket was swung. The material was released below the water surface within 10 to 20 feet of the bottom. Sediment grain size for the cap was a fine to medium sand that was less than 5 percent non-plastic silt. The contract was written so that the contractor was paid by the amount of material placed. Gravity probes were used to confirm that the project was successful; a final cap thickness of 6 to 9 inches was achieved. While the cost estimate ranged from

$3.4 to $5.5 million, the actual capping cost was $3.0 million. Post-cap monitoring was not required in this program.

# 7 CONCLUSIONS

The following conclusions are made regarding regulatory and institutional considerations for selecting and designing subaqueous ISC as a remedy component for the Lower Fox River:

- ISC is a technically feasible remedy approach for the Lower Fox River. However, there are several technical and institutional constraints on the application of capping at this site. Considering these constraints, capping could be a component of a remedy, but could not be the sole remedy for any OU. A combination of some capping and removal is likely the most efficient remedy.

- Technical, regulatory, and institutional issues would need to be appropriately considered in identifying potential areas for capping. Potential areas for capping should be selected based on the following:

  - ► The overall remedy must manage all sediments within the 1 ppm contour, and should achieve a sediment-weighted average concentration of 250 ppb. No capping would occur in designated navigation channels, with an appropriate setback in areas which may require dredging in the future.

  - ► No capping within authorized navigation channels (with an appropriate buffer).

  - ► No capping would occur in areas of infrastructure such as pipelines, utility easements, bridge piers, etc. (with appropriate buffer).

  - ► No capping would occur in areas with PCB concentrations exceeding TSCA levels.

  - ► No capping would occur in shallow-water areas (bottom elevations which would result in a cap surface at elevation greater than -3 feet chart datum for OUs 1 and 3 and -4 feet chart datum for OU 4) because of habitat and ice scour considerations without prior deepening to allow for cap placement.

- The composition and thickness of the cap components comprise the cap design. A detailed design effort for any selected capping remedy should address all pertinent design considerations.

- The cap will be designed to provide physical isolation of the PCB-contaminated sediments from benthic organisms.

- The cap will be physically stable from scour by currents, flood flow, and ice scour. The 100-year flood event will be considered in these evaluations.

- The cap will provide isolation of the PCB-contaminated sediments in perpetuity from flux or resuspension into the overlying surface waters.

- The performance criteria for chemical isolation will be a limit of 250 ppb of PCBs in the cap sediment (dry-weight basis) in the biologically active zone, defined as the upper 10 cm of the isolation layer of the cap. This standard would apply as a construction standard to ensure the cap is initially placed as a clean layer, and would also apply as a long-term limit with respect to chemical isolation.

- The cap design will consider operational factors such as the potential for cap and sediment mixing during cap placement and variability in the placed cap thickness.

- The cap design will incorporate an appropriate factor of safety to account for uncertainty in site conditions, sediment properties, and migration processes.

- Institutional/regulatory constraints associated with capping, such as capping TSCA materials, lake bed grants, riparian owner issues, deed restrictions, fiduciary responsibility, and long-term liability should be fully considered in selecting potential areas for capping and in design of the caps for specific areas.

- Application of these considerations is occurring as part of the detailed design component of the Lower Fox River project.

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# WHITE PAPER NO. 7 – LOWER FOX RIVER DREDGED SEDIMENT PROCESS WASTEWATER QUALITY AND QUANTITY: ABILITY TO ACHIEVE COMPLIANCE WITH WATER QUALITY STANDARDS AND ASSOCIATED WPDES PERMIT LIMITS

***Response to Comments Received on the***

## PROPOSED REMEDIAL ACTION PLAN FOR THE LOWER FOX RIVER AND GREEN BAY

January 2002


***This Document has been Prepared by***

Wisconsin Department of Natural Resources


**December 2002**

# WHITE PAPER NO. 7 – LOWER FOX RIVER DREDGED SEDIMENT PROCESS WASTEWATER QUALITY AND QUANTITY: ABILITY TO ACHIEVE COMPLIANCE WITH WATER QUALITY STANDARDS AND ASSOCIATED WPDES PERMIT LIMITS

## ABSTRACT

On October 5, 2001, the public comment period was opened for the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) developed by the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA) Region 5. Many comments were received during the comment period, which in part challenged the viability of the Proposed Plan based on discharge water quality and quantity concerns. In particular, the comment authors claimed that the dredging recommended in the Proposed Plan was not viable because the quality and quantity of wastewater generated in the dredging process could not comply with Water Quality Standards (WQS) and associated WPDES permit limits, even using the most advanced wastewater treatment process. The wastewater quantity and quality limitations would, therefore, restrict the allowable wastewater discharge rate, thereby decreasing the allowable dredging rate and increasing the dredge schedule from the 7 years estimated in the Proposed Plan to as much as 37 to 60 years. Based on these assumptions, the comment authors concluded that in-place sediment capping was the only viable alternative for remediation of the Lower Fox River sediment.

In response to these comments, the WDNR analyzed the assumptions used to support the comment conclusions, and performed an evaluation to determine if the expected dredge process wastewater characteristics and volumes would restrict or limit the viability of the Proposed Plan as claimed in the comments. This White Paper provides a summary of WDNR's analyses and responses to these comments. This analysis concludes that dredge process wastewater quantity and/or quality do not restrict the viability of dredging as recommended in the Proposed Plan, and do not justify capping.

## COMMENT SUMMARY

Although the comments were quite voluminous, they have been condensed to the following key issues and assumptions summarized below. The comments discussed in this White Paper and the following comment summary are based on a report received from a panel of scientists and engineers hired by Appleton Papers, Inc., referred to as the API Panel. The API Panel report is titled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (Panel Report) (The Johnson Company, 2002). Many of these comments were also provided by other companies, organizations, or individuals, but they were all based on or similar to the Panel Report, and are therefore addressed in this White Paper.

1) The comment authors claimed that remediation process wastewater must be treated to meet the most restrictive federal and state WQS and requirements prior to discharge to the Lower Fox River. Wisconsin Pollution Discharge Elimination System (WPDES) rules preclude the issuance of a discharge permit if a discharge will not attain WQS. The WQS for Bioaccumulative Chemicals of Concern (BCCs) for new or increased discharges must be the most stringent of those parameters contained in Wisconsin Administrative Code (WAC) Chapter NR 105.

2) The comment authors claimed that no assimilative capacity is available for biological oxygen demand (BOD) since that capacity is already fully allocated.

3) The comment authors claimed that wastewater generated in the remediation process at their estimated rate of 4.3 million gallons per day (mgd) in Operable Unit 1 (OU 1), and 23.7 mgd in OUs 3 and 4, even using the most advanced treatment technology, can not achieve the applicable WQS and associated WPDES permit limits.

4) The comment authors claimed that the expected wastewater discharge rate and quality would exceed the assimilative capacity of the Lower Fox River. Assuming the very best treatment results reported, the assimilative capacity of the River restricts the maximum discharge rate to 4.25 mgd, based on assumed treated effluent concentrations of dieldrin, endrin, cadmium, and mercury.

5) The comment authors claim that the wastewater generation rate should be 4,100 gallons per cubic yard (gal/cy) of dredged sediment, which is five times the rate contained in the Proposed Plan. This assumption increases the volume of dredge process wastewater needing treatment from the 0.7 to 5.0 mgd estimated in the Proposed Plan to the API Panel estimate of 4.3 to 23.7 mgd.

6) The comment authors claim that a maximum wastewater discharge rate of 4.25 mgd and a wastewater generation rate of 4,100 gal/cy of dredged sediment results in a maximum dredge rate of 1,050 cubic yards per day (cy/day), which extends the estimated dredge schedule from the Proposed Plan estimate of 7 years to as much as 37 to 60 years.

## ANALYSIS OF COMMENTS AND ASSOCIATED ASSUMPTIONS

### Ability of Dredge Process Wastewater to Comply with WQS and Associated Permit Limitations

#### *General Response*

This comment essentially said that remediation process wastewater must meet applicable state and federal requirements, and that WPDES rules preclude the issuance of a discharge permit if the discharge will not achieve WQS, and that WQS for BCCs for new or increased discharges must be the most stringent standard contained in WAC Chapter NR 105. The WDNR agrees that any wastewater discharge must meet state and federal requirements but does not agree that those requirements restrict the wastewater discharge to the extent concluded in the comment. This comment contains two major issues requiring a response.

The first issue is that of whether the remediation process wastewater discharge should be considered a new or increased discharge. Although the discharge of remediation process wastewater could be considered a new or increased discharge, realistically the discharge is not new and is not a net increase, since the sediment is already in the Lower Fox River and contributing contaminants to the system. In fact, another comment from the same author points out the placement of the Lower Fox River and inner Green Bay on the Clean Water Act's (CWA's) Section 303(d) list, as impaired waters not currently meeting WQS, is in part due to the sediment contribution of polychlorinated biphenyls (PCBs), 4,4'-Dichlorodiphenyl trichloroethane (DDT), dieldrin, arsenic, and mercury. Although there may be a short-term increase of contaminants in the water column from the dredging process, the net long-term reduction in the overall presence and contribution of contaminants from the sediment outweighs the short-term increase. It is, therefore, most appropriate to view the remedial dredging project as an action to reduce or eliminate an existing discharge of contaminants. Although this view does not actually change how limits are calculated under Wisconsin regulations, it is important in maintaining perspective of the project goal to remove contaminants, and their associated impacts, which are already present in the River system.

The second issue is that of whether Wisconsin's regulations limit the WDNR's ability to issue a WPDES permit in this case, and if the most restrictive permit limits would apply. Wisconsin rules do not require the application of the most restrictive WQS as the permit limit in cases where the receiving water background concentration exceeds the WQS. Chapter NR 106 is the WAC containing the requirements for the calculation of water quality based effluent limits for toxic and organoleptic substances discharged to surface waters. NR 106.06(6) WAC establishes the conditions under which alternative limits based on background concentrations are determined and provides the flexibility to apply a Net Environmental Benefit concept when addressing situations such as this, where the contaminants are already in the system. This section of the code essentially says that whenever background concentrations for toxic or organoleptic substances in the receiving water exceed the applicable WQS, and at least 10 percent of the source water is from the receiving stream, the effluent limit for that substance may be set at the background concentration, or an alternate limit or requirement may be determined. An alternate limit or requirement may be determined if the discharger's relative contribution of the mass of the contaminant to the receiving water body is negligible in the best professional judgment of the WDNR, and if the WDNR judges that Best Demonstrated Treatment Technology Reasonably Achievable (BDTTRA) is provided. The alternate limit or other requirement may include one or more of the following permit conditions, a numerical limit (which can be greater or lower than the WQS), a monitoring requirement, or a cost-effective pollutant minimization program (which could include a specific treatment technology or performance standard).

Since the Lower Fox River is actually 100 percent (far greater than 10 percent) of the source water, and background concentrations exceed the WQS for PCBs and mercury, which are toxic substances, subject to the provisions of NR 106 WAC, alternative limits are appropriate for these substances. DDT and dieldrin were not detected, and arsenic was either not detected or not present at levels requiring permit limits in the Deposit N and Sediment Management Unit (SMU) 56/57 demonstration project effluents. Application of the same or similar technology utilized in the demonstration projects is considered by the WDNR to be BDTTRA, and the PCB and mercury mass contained in the wastewater discharge are considered negligible. Therefore, the application of alternative limits or requirements other than background concentrations is reasonable, appropriate, and fully in conformance with existing rules.

## Specific Response

### Determination of Probable WPDES Permit Limits:

The comment conclusions that remedial dredging is not a viable option are predicated on the assumption that the allowable wastewater discharge rate is limited by the Lower Fox River's assimilative capacity, applicable WQS, and associated WPDES permit limits. In response, the WDNR's Bureau of Watershed Management completed two evaluations of the need for WPDES permit limits, copies of which are attached to this paper as Attachments 1 and 2. The subject line of Attachment 1 is "Discharge Limitations for the Proposed Discharges for the Fox River PCB Remediation Projects," (WDNR, 2002a) and addresses the need for Water Quality Based Effluent Limits (WQBELs) for toxic compounds. The subject line of Attachment 2 is "Unused Lower Fox River Assimilative Capacity in Clusters I, II, and III," (WDNR, 2002b) and addresses the question of Lower Fox River BOD assimilative capacity availability for the proposed sediment remediation plan. The WDNR evaluated effluent quality data and bench-scale testing Priority Pollutant (PP) data from the Lower Fox River Deposit N and SMU 56/57 demonstration projects, along with the estimated discharge rates contained in the Proposed Plan and those estimates provided in the comments. As part of the demonstration projects, four separate sets of treated effluent samples were analyzed for the PP. Two were from bench-scale tests using Deposit N and SMU 56/57 sediment as part of the pre-design phase of the projects. The other two analyses were from effluent collected during normal operation of the actual Deposit N and SMU 56/57 demonstration projects in 1998 and 1999. Since the same or equivalent wastewater treatment technology applied in the demonstration projects is proposed for full-scale remediation, it is assumed that full-scale effluent quality will be similar to and representative of the demonstration project effluent quality. A summary of that effluent data is provided in Table 1, on page 8 of this report.

### WQBELs for Toxic Compounds: PCBs and Mercury

Considering the expected full-scale wastewater discharge volumes and quality, and Wisconsin Water Quality Standards and associated WQBEL calculation requirements, the WDNR determined (see Attachment 1) that PCBs, mercury and ammonia were the only three compounds of concern at this time. No other compounds were identified as needing limits because they were not found in the demonstration project effluents at levels of concern, in fact most compounds were below the level of detection (LOD).

This current permit limit evaluation is consistent with the two 1998 WPDES permit limit determinations for the Deposit N and SMU 56/57 demonstration projects. When carbon adsorption treatment was utilized, even without application of a zone of initial dilution

(ZID) calculation, the only toxic substances requiring limits were PCBs, mercury and dioxin. Only PCB limits were determined using an alternate limit approach. WPDES permit limits were not needed for any other toxic substance when calculated using Wisconsin regulations and standard protocol, even without a ZID or any other special consideration. Since permit limits were determined in 1998, significant additional effluent data from those projects was obtained and used as the basis for the WDNR's current evaluation of the need for permit limits. Consideration of the additional data confirms the appropriateness of the 1998 limits determination and results in a similar conclusion in this current evaluation, except for the elimination of the need for dioxin limits.

The comment authors provided an extensive analysis and interpretation of various federal and state regulations, which led to their conclusion that the quantity and quality of dredge process wastewater limited the viability of the Proposed Plan. They did not, however, account for the flexibility built in to the regulations, and did not use effluent data representative of the demonstration projects. This resulted in the overestimation of expected effluent concentrations for several toxic substances and an overestimation of the need for permit limits and their associated impacts on the viability of the Proposed Plan. When the appropriate representative effluent data is used in the evaluation of the need for WPDES permit limits for toxic substances using standard Wisconsin regulations and protocol, only PCBs and mercury were identified as needing limits, which can be addressed through the alternate limit process provided in NR 106.06(6).

The evaluation in Attachment 1 provides a description of the methodology the WDNR will use in the development of PCB and mercury WPDES limitations for the proposed sediment remediation project. The discussion points out that since PCBs and mercury are BCCs, they would normally be limited to levels equal to the lowest water quality criteria (WQC), which are well below the current level of detection. However, since the Lower Fox River background concentrations already exceed the WQC for PCBs and mercury, WAC NR 106.06(6)(c) and (d) allows for the application of alternate effluent limits or requirements, as provided in the actual code language below:

**NR 106.06(6) (c) & (d)**
*NR 106.06(6)(c)*

1. Whenever the representative background concentration for a toxic or organoleptic substance in the receiving water is determined to be greater than any applicable water quality standard or criteria for that substance and the source of more than 10% of the wastewater for any discharger is from the same receiving water, the effluent limitation for that substance shall, except as provided in subd. 2., equal the representative background toxicant concentration of that substance in the receiving water as determined by the department, or an alternate limitation or requirement may be determined according to par. (d).

2. The department may establish an effluent limitation more stringent than the representative background concentration when the existing treatment system has a demonstrated and cost-effective ability to achieve regular and consistent compliance with a limitation more stringent than the representative background concentration.

*NR 106.06(6)(d)*

(d) Where appropriate, for effluent limitations determined under pars. (b) and (c), the department may conduct an analysis for a toxic or organoleptic substance which accounts for all sources of the pollutant impacting a waterbody or stream segment. In the event the discharger's relative contribution to the mass of the toxic or organoleptic substance impacting the waterbody or stream segment is negligible in the best professional judgment of the department, and the concentration of the substance in the discharge exceeds the representative background concentration of the substance, the department shall establish an alternative effluent limitation for the discharger. In determining whether the discharger's relative contribution to the mass of the substance is negligible, consideration shall be given to the type of substance being limited, the uses of the receiving water potentially affected and other relevant factors. The alternative effluent limitation or other requirement shall represent in the judgment of the department, application of the best demonstrated treatment technology reasonably achievable. An alternative effluent limitation or other requirement may include one or more of the following permit conditions:

1. A numerical limitation for the substance;
2. A monitoring requirement for the substance; or
3. A cost-effective pollutant minimization program for the substance as defined in s. NR 106.04(5).

The WDNR's evaluation concluded that the conditions for application of an alternate limit or requirement were met, and has determined that it is appropriate to apply the provisions of NR 106.06(6)(c) or (d) to establish limits for this project.

***Determination of Negligibility:***

As noted, the background concentration in the Lower Fox River is greater than the water quality criterion for PCBs and mercury. Under this condition, the WDNR, in implementing this part of the rule, must first establish that the discharge is negligible, in the best professional judgment of the WDNR. The concentration and mass of PCBs and mercury expected in the effluent are only a small fraction of the PCBs and mercury already annually released from the sediment and transported in the water column, and an even smaller fraction than that contained in the sediment.

The *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a) estimates that from 275 to 620 pounds per year (lbs/yr) of PCBs, and an average of 220 lbs/yr of mercury (range of 22 to 661 lbs/yr) were transported in to Green Bay from the Lower Fox River during the last decade. The expected effluent PCB concentration is below the 0.3 micrograms per liter (µg/L) LOD, and mercury is below the 0.5 nanograms per liter (ng/L) LOD. Assuming the effluent PCB and mercury concentrations are actually at the LOD, and assuming the wastewater discharge rates estimated in the Proposed Plan (0.7 mgd in OU 1, and 5.1 mgd in OUs 3 and 4), the discharge of PCBs would be 4.8 lbs/year (0.8 to 1.7 percent) of the current annual total load), and the discharge of mercury would be 0.0082 lbs/yr (0.004 percent) of the current annual mercury total load. Assuming the actual effluent concentrations are realistically well below the LOD, the actual discharge mass of PCBs and mercury is likely much lower than this analysis shows.

The removal of sediment results in a very substantial net reduction of PCB and mercury mass in the Lower Fox River system, and does not introduce any new contaminants to the system. The Proposed Plan recommends the removal of 29,250 kilograms (kg) (64,600 pounds) of PCBs from the system, while less than 13.6 kg (30 pounds) or 0.04 percent would be returned in the effluent over the 7-year length of the project. Leaving the sediment in the River just one additional year results in the release of 10 times more PCBs to the River from the sediment than would occur in 7 years of effluent discharge from the full-scale project. Although no mass mercury calculations have been determined for the 7.3 million cubic yards (cy) of proposed sediment removal, there is clearly a similar net removal of mercury from the system. The WDNR has determined, therefore, that the discharge from this project is negligible in accordance with the provisions in NR 106.06(6)(d) WAC.

Further support of this determination of negligibility is provided by the demonstration projects which showed only a small fraction of the mass of PCBs and mercury removed in the sediment was returned in the effluent or released during the dredging process. Significant monitoring was performed and reported on the 1999 SMU 56/57 demonstration project by Montgomery Watson, the United States Geological Survey (USGS), and Blasland, Bouck & Lee (BBL). The data shows that while 1,441 pounds of PCBs, and 30.3 pounds of mercury were removed from the River in the dredged sediment, that only about 0.3 pound or about 0.02 percent of the PCB mass, and about 0.0076 pound or 0.025 percent of the mercury mass was returned to the River via the effluent. The USGS and BBL reports also estimated the release of PCBs to the River from the dredging process, which showed that about 32 to 48 pounds of PCBs or 2.5 to 3.3 percent of the mass of PCBs dredged was released during the dredge process. According to the USGS report, this release represents only about 9 percent of the 409 pounds of PCBs annually transported by the Lower Fox River in 1994–1995.

The year 2000 SMU 56/57 demonstration project also showed that of the 670 pounds of PCBs removed in the dredged sediment, less than 0.143 pound or 0.02 percent of the PCB mass was returned via the effluent. It should be noted that in both the 1999 and 2000 SMU 56/57 demonstration projects, only one effluent sample had a detectable concentration of PCBs, while all the other samples were below the 0.26 to 0.33 PCB analytical level of detection (LOD).

***Application of BDTTRA:***

As part of the alternate limit eligibility determination, the WDNR must determine that the BDTTRA is being applied. Based on the performance of the Lower Fox River Deposit N and SMU 56/57 demonstration project wastewater treatment technology, which included sand filtration and granular activated carbon (GAC) adsorption, and considering EPA treatment manuals referred to in Attachment 1, the WDNR has determined that this same or similar technology represents the application of BDTTRA for PCBs and mercury. Sand filtration and GAC is the technology utilized in the *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b) cost analyses of alternatives. Based on the wastewater treatment performance in these projects, the WDNR expects effluent quality from the full-scale projects to achieve PCB concentrations less than 0.1 to 0.5 µg/L, and mercury concentrations less than 0.2 to 0.5 ng/L. These expectations will be factored into the determination of alternate limits as part of the actual permit limit determination process as implementation of the final Proposed Plan proceeds.

### *WQBELs for Toxic Compounds: Ammonia*

Ammonia in the dredge process wastewater was also identified as a concern, due to its toxicity and dissolved oxygen demand. In fact, comments received after the official comment period ended indicated effluent ammonia was one of the most significant reasons dredging was not feasible.

The WDNR's Bureau of Watershed Management evaluated the need for ammonia effluent limits using the demonstration project effluent data, background receiving water data, and expected discharge flow rates. Although demonstration project effluent ammonia data shows some values as high as 49 milligrams per liter (mg/L), those instances of higher ammonia levels were associated with the startup period of Deposit N, and in the first 6 weeks of SMU 56/57 (1999) due to design and associated operational problems. After wastewater treatment system improvements were completed at SMU 56/57 in 1999, the average effluent ammonia concentration was 8 mg/L and the average at Deposit N was 6 mg/L. These values are representative of the typical effluent quality expected from the full-scale project. Under these conditions, effluent ammonia limitations are substantially greater than expected effluent quality; therefore, it is expected that ammonia limits will not be needed.

Although effluent limits were not actually calculated as part of this exercise, a weekly average summer ammonia limit of 12 mg/L for the De Pere Wastewater Treatment Facility was determined in 2001 using a design flow of 14.2 mgd, which is almost three times the Proposed Plan estimated discharge rate of 5 mgd.

Another factor which needs to be considered is that Wisconsin's ammonia standard is currently under review, and that current drafts indicate summer (warm water season) criteria may be increased, potentially making expected effluent ammonia concentrations even less of an issue. The need for effluent ammonia limits for a full-scale dredging operation will of course be reevaluated as the implementation process and associated permitting proceeds.

Although the WDNR has determined that under the expected full-scale dredging conditions ammonia limits will not be needed, there are a number of other factors which should be considered when evaluating the ammonia issue. First, as with PCBs and mercury, the effluent ammonia comes from the sediment, which is already in the system, so the discharge does not represent any new contribution to the system. Although there does not appear to be Lower Fox River sediment research that quantifies the flux of ammonia from the sediment into the water column, there is significant sediment pore water data which does document high levels of ammonia in the sediment. Given the dynamic hydrology of the Lower Fox River, and the solubility and volatility of ammonia, and the fact that PCBs and mercury are moving from the sediment into the water column, the sediment is also currently considered a source of ammonia to the water column. The WDNR believes that removal of much of the soft sediment will remove much of the existing reservoir of ammonia resulting in a net reduction of ammonia input to the system. Therefore, even if a portion of the sediment ammonia is released back into the receiving stream via the wastewater discharge, the sediment source and associated ammonia release is removed, thereby eliminating, at least temporarily, substantial future releases.

Another consideration is that ammonia, unlike PCBs and mercury, is readily biodegradable. In the biodegradation process known as nitrification, ammonia is converted to nitrate, a non-toxic form of nitrogen. As part of this process, oxygen is consumed, thus exerting a BOD. As pointed out in the following discussion on Wasteload Allocation (WLA), there is a substantial unused assimilative capacity, which far exceeds the BOD demand of the nitrification process. But more importantly, the Lower Fox River WLA modeling effort, reported in a January 1980 report, concludes that Lower Fox River dissolved oxygen levels are very insensitive to the rate of nitrification because during the summer months most inorganic nitrogen (ammonia and nitrate) is utilized by algae before it is has a chance to be oxidized. As a consequence, the addition of ammonia at the expected levels would have little impact on the dissolved oxygen profile. The WDNR, therefore, believes that expected effluent ammonia does not limit the feasibility of the proposed dredging plan either by ammonia toxicity or dissolved oxygen depletion.

Although ammonia treatment/removal is not expected, if it were needed, there are technologies including chlorination/dechlorination, a standard wastewater treatment technology (personal communication with Mike Crystal), or pH adjustment which could be added.

### *Biochemical Oxygen Demand/Dissolved Oxygen: Fox River Assimilative Capacity*

Comments were received which concluded there is no assimilative capacity for BOD available for the proposed full-scale remedial dredging project because the Lower Fox River assimilative capacity is already fully allocated to other permitted dischargers. Although it is true that the Lower Fox River's assimilative capacity for BOD is fully allocated, it is commonly understood that, because of the high level of treatment being provided by existing dischargers, much of that allocated load for most of the dischargers is not utilized. To evaluate this issue, the WDNR's Water Quality Modeling Section has calculated the difference between the allocated loadings and the actual discharged loadings. This effort was completed and reported in a June 3, 2002 memorandum, a copy of which is attached.

Over 20 years ago, the Lower Fox River assimilative capacity for BOD was determined by development of a sophisticated WLA model and allocated to the permitted dischargers. This allocation was adopted in NR 112 WAC. Information from NR 112 has been used to develop tables that are placed in the discharger's WPDES permits. These tables established the WLA permit limits for BOD based on various river flows and temperatures. The model divided the River and the associated dischargers into three clusters, which roughly correspond to the four OUs established in the Proposed Plan. Cluster I corresponds to OU 1, Cluster II corresponds to OU 2, and Cluster III includes OUs 3 and 4.

The analysis reviewed wastewater discharge data from 1999 through 2001, and using the worst-case conditions, determined the minimum unused pounds per day of WLA for each discharger in each cluster for that 3-year period. The minimum difference between the permitted allocated load and the actual load for all the dischargers was totaled for each cluster. The results revealed, under the worst-case conditions, that the total difference ranged from 10,688 pounds per day (lbs/d) in Cluster I to 39,531 lbs/d in Cluster III. Under average river flow and temperature conditions, and applying the 1.2 to 1.34 multiplier to the daily maximum WLA permit limit as provided in the WPDES permits, the difference between the permitted loadings and the actual loadings would likely be at least two times the worst-case values shown here.

The BOD discharge expected from implementation of the full-scale dredging project was calculated. Based on the effluent quality obtained in the Lower Fox River demonstration projects, an effluent BOD concentration of 15 mg/L was selected, and effluent flows of 1.4 mgd for OU 1 and 10 mgd for OUs 3 and 4 were selected to calculate the daily BOD discharge anticipated from the project. These values are very conservative in that the flows used were twice the Proposed Plan's estimated flows of 0.7 mgd in OU 1 and 5 mgd in OUs 3 and 4. The assumed effluent BOD of 15 mg/L was just above the highest reported representative value of 13 mg/L in the demonstration projects, which is several times greater than the average effluent BOD concentration in those projects. The resultant conservative BOD discharge estimate from the full-scale dredging project is 175 lbs/d in OU 1, and 1,285 lbs/d in OUs 3 and 4.

Comparing the difference between the permitted loadings and the actual loadings to the estimated dredge process wastewater discharge reveals that the Proposed Plan would only use a maximum of 4.3 percent of the difference. If both OUs 3 and 4 process wastewater is discharged at the same time in Cluster II, as shown below, then the maximum loading is 8.6 percent of the difference. From this analysis, the WDNR has concluded there is substantial available allocated capacity that existing discharges are not using, and the discharge from implementation of the Proposed Plan will not have a significant impact on water quality. Again, this is a worst-case scenario. If typical effluent quality similar to that of the demonstration projects is discharged, the actual BOD discharge will be substantially below these estimates. This exercise also does not account for the fact that the sediment already exerts a significant oxygen demand upon the River, and that removal of the soft sediment results in removal of much of the sediment oxygen demand associated with that sediment.

| | Difference Between Permitted Allocations and Actual Discharges (lbs/d BOD) | Percent of Permitted Allocation (%) | Average Percent of Allocation Used (%) | Estimated BOD Discharge from Proposed Plan (lbs/d BOD) |
|---|---|---|---|---|
| Cluster I | 10,688 | 78.2 | 21.8 | 175 (1.6% of unused) |
| Cluster II | 29,536 | 30.2 | 30.2 | 1,285 (4.3% of unused) |
| Cluster III | 39,531 | 77.5 | 22.5 | 1,285 (3.3% of unused) |

Based upon the difference between the permitted allocations and the actual discharges for each of the companies responsible for the release of PCBs (see Attachment 2), the estimated wastewater BOD load from the proposed remediation plan is significantly less than this difference. Given that these companies discharge at levels much less than their current allocated loadings, it is the WDNR's intent to either formally or informally temporarily transfer a portion of that unused capacity from those companies to the proposed Lower Fox River Remediation Project. This was informally done with the Lower Fox River demonstration projects.

### *Advanced Treatment Technology Ability to Achieve Applicable Water Quality Standards*

Comment authors concluded that achieving compliance with expected WQBEL would require wastewater treatment far exceeding Best Demonstrated Available Technology (BDAT) which would require the application of unproven technology with many associated risks. The comment author's report includes a table (Table B-4) comparing the expected performance from BDAT treatment to anticipated WPDES Permit WQBELs which showed compliance with WQBELs was not achievable. This analysis and conclusion are not supported by the effluent PP data from the Lower Fox River Deposit N and SMU 56/57 demonstration projects, which are orders of magnitude lower than that cited for BDAT in the report. Comparison of the assumed BDAT effluent to the demonstration project effluent quality reveals that the BDAT values are not appropriate to use in this case because they do not adequately represent the effluent quality expected from the proposed project. The comment authors also calculated WQBELs, except for NR 106 alternate limits, which when compared to the demonstration project effluent data show that dredge process wastewater can achieve compliance with expected limits for all parameters except PCBs and mercury, as shown in the following table. Although the WQBELs determined by the comment authors were not verified as part of this analysis, the WDNR's evaluation of permit limits reached the same conclusion, except that WQBELs could be determined for PCBs and mercury using the NR 106 alternate limit approach. Since the Proposed Plan effluent quality is expected to be equivalent to the demonstration project effluent quality, it is the WDNR's determination that application of the same or similar treatment technology will achieve compliance with WQBELs. The wastewater treatment technology applied in the demonstration projects was sand filtration and activated carbon absorption, which is not unproven, but is standard technology applied in similar remediation projects around the world.

## TABLE 1

| Parameter | Demonstration Project Effluent Quality (µg/L unless otherwise indicated) | | | | | Panel Report Values Obtained from Tables B-2, B-3, B-4, and B-9 (µg/L) | | |
|---|---|---|---|---|---|---|---|---|
| | SMU 56/57 1999 | SMU 56/57 2000 | SMU 56/57 Bench | Deposit N | Deposit N Bench | [3] Best Reported Treatment Results | [4] BDAT (EPA, 1995) | WQBELs Calculated by API Panel |
| ***Non BCCs*** | | | | | | | | |
| Ammonia (mg/L) (before WW improv.) | [2] 1.6–49 (Ave 16.5) | 16, 26 | 34 | 0.062–29 (Avg 6.0) | 6.1 | | | |
| Ammonia (mg/L) (after WW improv.) | [2] 1.6–17 (Avg 8.0) | | | | | | | |
| Antimony | < 6.4 | | < 6.7 | < 4.7 | 8.5 | | | |
| Arsenic | < 9 | | < 4.7 | < 5.9 | 5.5 | 5 | 20–200 | 50 |
| Cadmium | < 0.83 | | < 0.37 | < 0.56 | 2.4 | 20 | 200 | 1.4–3.8 |
| Chloride (mg/L) | | | 32 | | 21 | | | |
| Chromium$^{+6}$ | < 8.2 | | < 6.7 | < 8.2 | < 6.7 | 10 | 370 – Total Cr | 11 ($Cr^{+6}$) |
| Chromium (Total) | < 2.0 | | < 0.64 | < 0.6 | < 0.64 | | 370 – Total Cr | 75–233 ($Cr^{+3}$) |
| Copper | < 4.7 | | 2 | < 1.6 | 16 | 20 | 1,300 | 6.6–21.6 |
| Lead | < 4.4 | | < 2.4 | < 3 | 3.3 | 30 | 280 | 14–55 |
| Nickel | < 3.7 | | < 4.0 | 7.5 | 12 | 100 | 550 | 72–271 |
| Selenium | < 8.4 | | < 4.8 | < 9.4 | < 0.33 | | 820 | 5 |
| Silver | < 0.8 | | < 2.4 | < 0.43 | < 2.4 | | | |
| Zinc | < 5.6 | | 14 | 5 | 10 | 200 | 1,000 | 66–221 |
| Pentachlorophenol | < 3.7 | | < 2.4 | < 2.5 | < 2.4 | 13 | 89 | 5.33–48.7 |
| Fluoranthene | < 0.45 | | < 0.021 | < 0.021 | < 0.023 | | | |
| Endrin | < 0.01 | | < 0.099 | < 0.018 | < 0.006 | 1 | 2.8 | 0.072 |
| ***BCCs*** | | | | | | | | |
| Dieldrin | < 0.011 | | < 0.099 | < 0.013 | < 0.0049 | 1 | 17 | 2.70 E-06 |
| Mercury | < 0.0001–0.1018 | < 0.001–0.00045 | < 0.0097 | < 0.0001 | < 0.0097 | 0.25 | 150 ($Hg^{+2}$) | 0.0013 |
| PCBs | < 0.33 (1 @0.37) | < 0.26 | < 0.31 | < 0.33 [1](< 0.7–1.6) | < 0.011 | | 13–17 | 3 E-06 |
| 4,4'-DDT | < 0.013 | | < 0.023 | < 0.022 | < 0.013 | | | 1.1 E-05 |
| 2,3,7,8-TCDD (pg/L) | < 7.1 | | < 2.7 | < 4.8 | < 0.8 | | 0.063 µg/L | 3 E-09 |

**Notes:**

[1] These values are from the first 2 weeks of the project.

[2] The 1999 SMU 56/57 data provided in the top cell is for the overall project performance and the data in the next cell below is only for that period after wastewater modifications were completed 6 weeks into the project, which is considered more representative of a properly operating treatment facility.

[3] Best Reported Treatment Results values obtained from 1985 text, *Industrial Wastewater Treatment Technology*, by J. W. Patterson.

[4] BDAT – Best Demonstrated Available Technology (EPA, 1995) as presented in the Panel Report dated December 20, 2001.

### *Limitation of Proposed Process Wastewater Discharge Rate Based on Assumed Effluent Cadmium, Dieldrin, Endrin, and Mercury Concentrations*

Comment authors concluded the assimilative capacity of the Lower Fox River would limit the discharge rate of sediment remediation process wastewater to 4.25 mgd, based on assumed effluent concentrations of dieldrin, endrin, mercury, and cadmium. This conclusion is apparently based on assumed effluent contaminant concentrations, which were described as "Best Reported Treatment Results" and obtained from a 1985 text authored by J. W. Patterson (one of the comment authors). Using these assumed concentrations, the maximum wastewater discharge rate, which would not exceed the assimilative capacity of the River was calculated to be 8.4 mgd for cadmium, 1.25 mgd for mercury, and 3.12 mgd for endrin, producing an average of 4.25 mgd. Dieldrin had a much lower assimilative capacity based discharge rate of 0.04 mgd, but was discounted.

As in the previous discussion, these conclusions are not based on representative data. They did not consider the Lower Fox River demonstration project effluent data, which the WDNR believes is the most appropriate data to use in estimating future effluent quality from the proposed Lower Fox River remediation project.

Review of the four demonstration project PP data sets reveal that dieldrin and endrin were not detectable at LODs of 10 to 100 times lower than the Panel Report-assumed values. Since dieldrin and endrin were not detected in any effluent samples, permit limits would not be given for these parameters using normal limit setting procedures; therefore, the discharge rate would not be influenced or limited by these parameters.

Three of four samples did not detect cadmium at an LOD of 20 to 50 times lower than the assumed value, and one sample detected cadmium at an about one-tenth of the assumed value. These values are well below anticipated permit limits.

Mercury was the only parameter analyzed in three of the four PP data sets; however, it was also analyzed weekly during the demonstration projects. Mercury was not detected in any of the three PP analyses, with LODs of 10 to 1,000 times lower than the assumed value. During the SMU 56/57 year 2000 demonstration project, about 19 mercury samples were collected of which 14 had no detects at an LOD 2,000 times lower than the assumed value, and 5 values had detected concentrations, the highest of which was 500 times lower than the assumed value. The Deposit N and SMU 56/57 (year 1998) project effluent mercury values were mostly detectable at levels similar to those detected in SMU 56/57 (year 2000). Influent wastewater mercury analysis was also done on samples collected just prior to the wastewater treatment process. These mercury concentrations of untreated wastewater were also far below the assumed values used in the Panel Report for treated effluent. Mercury has, however, already been identified as having no available assimilative capacity because Lower Fox River background concentrations already exceed the mercury water quality standard, and is eligible for alternate permit limits.

Replacing the Best Reported Treatment Results assumed in the Panel Report with the actual Lower Fox River demonstration project effluent data, but keeping all the other assumptions the same, increases the assimilative capacity based wastewater discharge rate by a factor of at least 20, from 4.25 mgd to at least 80 mgd. Based on this analysis, the WDNR has concluded that the assimilative capacity of the Lower Fox River will not limit the discharge rate due to cadmium, dieldrin, endrin, mercury, or any other parameter.

### *Wastewater Generation Rate Impacts on Dredge Rate and Dredge Schedule*

The prior discussions address the comments that claim that the expected quality of the dredge process wastewater generated from implementation of the Proposed Plan would result in limitation of the discharge rate to 4.25 mgd. Additional comments took this maximum discharge rate of 4.25 mgd and projected its impact on the length of time it would take to complete dredging the 7.3 million cy of sediment recommended in the Proposed Plan. Although this subsequent projection of discharge volumes is not directly related to effluent quality and associated probable permit limits, it was used as the basis for concluding that dredging is not viable due to discharge volume, so it will be briefly discussed here.

The comment authors claim the wastewater generation rate from dredging would be about 4,100 gal/cy of dredged sediment, which is about five times the value used in the Proposed Plan. Using this 4,100 gal/cy value increases the volume of dredge process wastewater from the Proposed Plan estimates of 0.7 mgd in OU 1 and 5.0 mgd in OUs 3 and 4, to 4.3 mgd in OU 1 and 23.7 in OUs 3 and 4. The comments next assumed that based on a maximum allowable discharge rate of 4.25 mgd and a wastewater generation rate of 4,100 gal/cy of dredged sediment, the maximum allowable dredge rate would be about 1,050 cy/d, which would increase the Proposed Plan's estimated 7-year dredge schedule to as much as 37 to 60 years. These issues were addressed in detail in the Responsiveness Summary. The WDNR essentially concluded that an estimated wastewater generation rate of 4,100 gal/cy of dredged sediment is not reasonable, the dredge rate would not be limited to 1,050 cy/d and the Proposed Plan's estimated dredge rate of 5,770 cy/d is a reasonable expectation for the full-scale dredging process. The Proposed Plan's estimated 7-year dredge schedule is, therefore, still considered to be a reliable estimate. The determination was also made that even if wastewater generation rates were as high as the comments claimed, there would not be any limitation to the wastewater discharge rate and associated dredge rate or dredge schedule.

## CONCLUSIONS

This paper was written to address comments that claimed that the dredging recommended in the Proposed Plan for the Lower Fox River and Green Bay was not viable. This conclusion was based on the assumption that the quality and quantity of wastewater generated in the dredging process could not comply with WQS and associated WPDES permit limits, and that the quality and quantity of dredge process wastewater would restrict the allowable wastewater discharge rate, thereby decreasing the allowable dredging rate and increasing the dredge schedule from the 7 years estimated in the Proposed Plan to as much as 37 to 60 years.

This evaluation concludes that the expected quality and quantity of the dredge process effluent will comply with Water Quality Based Effluent Limits, and will not restrict the effluent discharge rate or associated dredge schedule. The expected effluent quality and quantity do not, therefore, limit the viability of the proposed remedial dredging project, and does not justify in-place sediment capping. Additional significant specific conclusions are as follows:

1) The dredge process effluent quality assumed by the comment authors is not representative of expected Lower Fox River dredge process effluent quality.

2) The wastewater quality achieved from the Lower Fox River Deposit N and SMU 56/57 demonstration projects provides the best representation of the effluent quality expected from the full-scale dredging of the Lower Fox River, and will be used for estimating expected effluent quality.

3) Effluent quality would not limit the ability of the project to comply with expected wastewater WPDES permit limits.

4) Effluent quality would not restrict the expected effluent discharge rate based on the Lower Fox River assimilative capacity for cadmium, dieldrin, endrin, mercury, or any other parameter.

5) WQBELs for toxic and organoleptic compounds regulated under WAC NR 106 are only needed for PCBs and mercury.

6) PCB and mercury WQBELs will be determined using the Alternate Limit procedures provided in NR 106.06(6) WAC, because background Lower Fox River concentrations of PCBs and mercury exceed WQS.

7) The Lower Fox River assimilative capacity for BOD is fully allocated, however, much of that capacity is unused by the permitted dischargers. Much of that unused capacity is held by the paper companies who are the potentially responsible parties for the PCB contamination of the River, and could be available for temporary use by this remediation project. Effluent from full-scale implementation of the proposed dredging plan would only use a small percentage (less than 10 percent) of the unused or available assimilative capacity of the River.

8) Effluent quantity estimates contained in the comments are not reasonable, do not limit the allowable dredge rate, and would not extend the dredge schedule beyond the 7 years estimated in the Proposed Plan.

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# ATTACHMENT 1
# DISCHARGE LIMITATIONS FOR THE PROPOSED DISCHARGES FOR THE LOWER FOX RIVER PCB REMEDIATION PROJECTS

# CORRESPONDENCE/MEMORANDUM

DATE: August 21, 2002

TO: Bruce Baker – AD/5

FROM: Al Shea – WT/2

SUBJECT: Discharge Limitations for the Proposed Discharges for the Fox River PCB Remediation Projects (Operable Units 1, 3, and 4)

This document describes the methodology the Department will use in the development of effluent limitations for the discharges from the proposed remediation projects to the Lower Fox River. It contains a discussion for applying the provisions of existing state water quality standards (including the calculation of water quality-based effluent limitations (WQBELs)) and the WPDES program in permits for the proposed discharges.

The substances discussed here are chosen because we feel these compounds are of the greatest concern, although limits for other substances may be calculated in the future as needed. Based on the projects themselves, compounds found in the water column and/or sediments, bioaccumulation potential, and assimilative capacity issues, the primary concerns at this time are related to PCBs, mercury, and ammonia.

## WQBELs FOR PCB AND MERCURY

PCBs and mercury are among the list of bioaccumulating chemicals of concern (BCCs) identified in current DNR rules (ss. NR 105.03(9), 106.06(2), and NR 207.02(6)(c), Wis. Adm. Code). New discharges of BCCs to the Great Lakes basin at this time, and all discharges to the Great Lakes basin after March 23, 2007, must meet effluent limits that are equal to the lowest water quality criterion available in ch. NR 105, Wis. Adm. Code. These criteria are much less than the current level of detection for these substances. For both PCBs and mercury, sampling data demonstrates that background concentrations in the Fox River are greater than the lowest criterion for each substance. Therefore, alternative effluent limitations may be considered for PCBs and mercury under ss. NR 106.06(6)(c) and (d), Wis. Adm. Code. Specifically, under the provisions of s. NR 106.06(6)(c), Wis. Adm. Code, whenever background is greater than the criteria and the source of wastewater is from the same body of water, effluent limitations may be set equal to the background concentrations of these substances or an alternative limitation or requirement may be established using the procedure in s. NR 106.06(6)(d), Wis. Adm. Code.

Section NR 106.06(6)(d), Wis. Adm. Code, authorizes the establishment of alternative limitations when (1) the discharger's relative contribution to the mass of the substance impacting the waterbody or stream segment is considered to be negligible in the best professional judgment of the Department and (2) the concentration of the substance in the discharge exceeds the representative background concentration. Under these circumstances, alternative limitations may be established based upon the Department's application of "the best demonstrated treatment technology reasonably achievable." The alternative effluent limitation may include one or more of the following:

1. A numerical limitation for the substance,
2. A monitoring requirement for the substance, or
3. A cost-effective pollutant minimization program for the substance as defined in s. NR 106.04(3).

The water discharged as a result of these projects will contain a small fraction of the contaminants that are already in place in the sediments of the Fox River. The removal of the sediments will significantly reduce the mass amount of PCB and mercury that may move from the sediment to the water over time. It will also reduce the amount of these substances that may enter Lake Michigan in the future. There will be no new introduction of contaminants to the system, but there will be a significant net removal from the system.

The projects being planned will remove approximately 29,250 kilograms of PCB that is currently in the system. It is estimated that the PCB discharged in the carriage return water from the dredging projects will be less than about 10 kilograms with the application of "best demonstrated treatment technology reasonably achievable" as described below. Because mercury will be similarly removed in the treatment processes employed, it is estimated there will be a similar significant net removal of mercury from the system. Thus, this discharge, in comparison to the overall net removal of substances from the river, represents a negligible contribution, in our judgment. Therefore, it is appropriate to use the provisions of NR 106.06(6)(d), Wis. Adm. Code, to establish effluent limitations for these projects.

LIMITATIONS FOR BEST DEMONSTRATED TREATMENT TECHNOLOGY

In conformance with the above-noted provision of NR 106.06, Wis. Adm. Code, the Department may establish effluent limitations for total PCBs and total recoverable mercury that represent the application of BDTTRA. This section of the memo will specify permit requirements for carriage return water that is generated during the remediation dredging projects on the Lower Fox River. These requirements represent the application of "best-demonstrated treatment technology reasonably achievable" (BDTTRA).

We have reviewed available information on the treatment technology that was used as part of the Fox River Deposit N, Deposit O and Sediment Management Unit (SMU) 56/57 remediation projects. That technology, or very similar technology, represents, in our judgment, "best-demonstrated treatment technology reasonably achievable" (BDTTRA). The sediments that are hydraulically removed from the river are processed through a system consisting of coagulant-assisted gravity settling and pH adjustment, with settled sediment dewatered using a plate and frame filter press. The settling basin supernatant and the press filtrate are treated by sand-filtration and are passed through granular activated carbon. PCB and mercury effluent quality from these projects and with this technology is superior to any presented by EPA in its *Manual Ground-Water and Leachate Treatment Systems* (EPA/625/R-94/005, January 1995) and *Treatability Manual* (EPA-600/2-82-001a, Reprinted February 1983). At the time permits are issued for these projects, there will be an additional evaluation of BDTTRA to determine if additional treatment technology is appropriate.

This BDTTRA technology is capable of attaining, as demonstrated in the aforementioned projects, an effluent total PCB concentration on a daily maximum basis of less than the limit of detection when using EPA Method SW-846 8082. Method SW-846 8082 should provide a limit of detection of 0.1 to 0.5 µg/L and, we believe this is the level of performance that can be achieved with the technology described above. Specifically, this is supported by effluent data from the SMU 56/57 project after October 16, 1999, when separate treatment of settling basin supernatant and press filtrate began.

As with PCB and, as demonstrated in the aforementioned projects, the dewatering and treatment technology described above is determined to be BDTTRA and is capable of attaining a performance level that produces effluent mercury concentrations of less than the limit of detection when using EPA Method 1631. Method 1631 should provide a limit of detection of about 0.2 ng/L and a minimum level (ML), which is roughly equivalent to the limit of quantitation, of 0.5 ng/L. This limitation is supported by effluent data from the second year of the SMU 56/57 project. The second year of the project is selected because operation of the treatment system was improved during the second year.

AMMONIA LIMITATIONS

Based upon the characterization of sediment quality (ammonia is a constituent in the sediment) and water discharged from sediment treatment facilities, effluent limitations for ammonia have also been evaluated. Because ammonia limitations depend on temperature and pH characteristics of the receiving water, we have evaluated the need for effluent limitations using background data recently used to calculate limits for municipalities along the Lower Fox River(e.g., Neenah – Menasha, Heart of the Valley and Appleton). This evaluation has also employed the Department's most reasonable estimate of flow volumes from the dredging project units. Under these circumstances, effluent ammonia limitations are substantially greater than projected effluent quality and ammonia limits will not be needed.

cc: Gary Kincaid – NER
Ed Lynch – RR/3

# ATTACHMENT 2
# UNUSED FOX RIVER ASSIMILATIVE CAPACITY FOR BOD

# CORRESPONDENCE/MEMORANDUM

DATE: June 3, 2002 FILE REF: 8250

TO: Gary Kincaid - NER

FROM: Jeff Kreider - WT/2

SUBJECT: Unused Lower Fox River Assimilative Capacity in Clusters I, II and III

The intention of this memo is to update the memo I wrote on May 2, 2002 to Gary Kincaid. This memo fixes an error in Table 1, where the Fort James East and Fort James West values were switched. This memo also includes the Cluster II table and incorporates the possibility of having the remediation discharge for the sediment dredged from Cluster III located in Cluster II.

The plan for the remediation of the PCB contaminated sediments in the Lower Fox River/Green Bay site, published in the October, 2001 proposes a combination of the remediation dredging and monitored and natural recovery to reduce the risks associated wit the site. According to the plan, hydraulic dredging would be conducted to remove the sediment and ultimately, the sediment would be dispose of at an upland disposal site. This process would result in a return flow of water after the transport and dewatering of the sediment.. Comments were received on the proposed plan questioning the feasibility of the proposed plan.

In a DRAFT memo to Ed Lynch from Jeff Haack, the Water Quality Modeling section was asked to look into the available assimilative capacity for the proposed remediation discharge in Clusters I and III.

Four dischargers were evaluated for potential load reductions to allow for the remediation discharge, in Cluster I, P.H. Glatfelter and American Tissue; in Cluster II, Appleton Paper; and in Cluster III, Fort James West. The analysis uses spreadsheets generated from the SWAMP system for years 1999-2001; information from 1999 and 2000 discharge data for the SMU 56/57 remediation; the individual NR 212 tables for the above mentioned dischargers; and only considers $BOD_5$. The spreadsheets from the Department's System for Wastewater Applications, Monitoring, and Permits (SWAMP) system contained all the data from the DMRs and needed to be reformatted to make them easier to use. Two columns were added and calculations completed: 'Unused WLA lbs/day' and 'WLA Percent Used'. The spreadsheets were sorted on the 'WLA Value' column showing the minimum WLA value used during the three year time period. The 'WLA Percent Used' column was evaluated to determine the maximum percentage used at the lower WLA values.

The analysis assumes a 1 : 3 $BOD_5$ : $BOD_{ult}$ ratio for the remediation discharge using the following equation.

$$(FL * FR * PU – RL * RR) / FR = RA$$

Where FL: facility load (lbs/day)
FR: facility $BOD_5$ : $BOD_{ult}$ ratio
PU: Percent of unused allocation
RL: remediation discharge load (lbs/day)
RR: remediation discharge $BOD_5$ : $BOD_{ult}$ ratio
RA: remaining unused wasteload allocation

The analysis uses the smallest number indicated in the NR 212 tables (low flow, high temperature) which is the worst case scenario condition for each discharger listed above. Then the minimum percentage of the discharger's unused wasteload allocation is multiplied by the NR 212 number giving the unused portion of the discharger's wasteload allocation.

## Cluster I

The maximum projected flow (two times the projected flow) for the remediation discharge is 1.39392 MGD. The maximum concentration in the SMU 56/57 discharge was 13 mg/l after the treatment system was redesigned in the first

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year after October 16, 1999. This number was rounded up to 15 mg/l to remain on the conservative side for this analysis. The maximum projected $BOD_5$ load is then 175 lbs/day.

Based on the information provided in the SWAMP generated spreadsheets, P.H. Glatfelter used no more than 23% of their wasteload allocation and American Tissue used no more than 43% of their wasteload allocation. Using the NR212 tables, at worst case scenario (low flow, high temperature) conditions, P.H. Glatfelter is allocated 4017 lbs/day and Wisconsin Tissue is allocated 1462 lbs/day. The intent of scenarios 1 and 2 is to show each facility's remaining wasteload allocation after all or some portion of the remedial discharge's wasteload allocation has been removed.

## Scenario 1 – Take All Projected Remediation Discharge from A Single Discharger

### Scenario 1A

P.H. Glatfelter - The remaining unused allocation is 2812 lbs/day (Eq. 1).

(4017 * 1.87 * (100% - 23%) - 175 * 3) / 1.87 = 2812 lbs/day Eq. 1

### Scenario 1B

American Tissue - The remaining unused allocation is 738 lbs/day (Eq. 2).

(1462 * 5.5 * (100% - 43%) - 175 * 3) / 5.5 = 738 lbs/day Eq. 2

## Scenario 2 – Use Weighted Distribution of Remediation Discharge

Considering only P.H. Glatfelter's and American Tissue's discharge, P.H. Glatfelter has 73.3% of the total discharge and American Tissue has the remaining 26.7%. P.H. Glatfelter's remaining unused allocation is 2887 lbs/day (Eq. 3) and Wisconsin Tissue's remaining unused allocation is 808 lbs/day (Eq. 4).

(4017 * 1.87 * (100% - 23%) – 175 * 3 * 73.3%) / 1.87 = 2887 lbs/day Eq. 3

(1462 * 5.5 * (100% - 43%) – 175 * 3 * 26.7%) / 5.5 = 808 lbs/day Eq. 4

## Cluster II or III

The maximum projected flow (two times the projected flow) for the remediation discharge is 10.26144 MGD. The maximum concentration in the SMU 56/57 discharge was 13 mg/l after the treatment system was redesigned in the first year after October 16, 1999. This number was rounded up to 15 mg/l to remain on the conservative side for this analysis. The maximum projected $BOD_5$ load is then 1285 lbs/day. The intent of scenarios 1 and 2 is to show each facility's remaining wasteload allocation after all or some portion of the remedial discharge's wasteload allocation has been removed.

## Scenario 1 – Remediation Site Located In Cluster II

Based on the information provided in the SWAMP generated spreadsheets, Appleton Paper used no more than 56.2% of their wasteload allocation. At worst case scenario conditions, Appleton Paper is allocated 3509 lbs/day. Under these conditions Appleton Paper's remaining unused allocation is 810 lbs/day (Eq. 5).

(3509 * 5.3 * (100% - 56.2%) – 1285 * 3) / 5.3 = 810 lbs/day Eq. 5

## Scenario 2 – Remediation Site Located In Cluster III

Based on the information provided in the SWAMP generated spreadsheets, Fort James West used no more than 8.5% of their wasteload allocation. At worst case scenario conditions, Fort James West is allocated 8979 lbs/day. Under these conditions Fort James West's remaining unused allocation is 7445 lbs/day (Eq. 6).

(8979 * 5 * (100% - 8.5%) – 1285 * 3) / 5 = 7445 lbs/day Eq. 6

## Additional Information

Table 1 shows the amount of unused wasteload allocation at the observed lowest flow, highest temperature condition for the Lower Fox River. The reason for using this condition is that the river flow and temperature does not change significantly within the cluster, therefore all percentages are near the same time period. As the table indicates, Cluster I had 10,688 lbs/day of available allocation, Cluster II had 29,536 lbs/day of available allocation and Cluster III had 39,531 lbs/day of available allocation. As flow increases and/or temperature decreases the available allocation will generally increase for the clusters.

To better understand the impact on the water quality by the remediation discharges in Cluster I and III for $BOD_5$, the amount of dissolved oxygen depleted from the water column was calculated. Based on the low flow of 750 cfs found in the NR 212 tables for the Lower Fox River, a $BOD_5$ load of 4045 lbs/day would deplete the dissolved oxygen 1 mg/l. Therefore, the dissolved oxygen depletion due to the remediation discharge in Clusters I (175 lbs/day / 4045 lbs/day) and II or III (1285 lbs/day / 4045 lbs/day) are 0.043 mg/l and 0.32 mg/l respectively. Generally the accuracy of a dissolved oxygen meter is 0.2 mg/l.

If the decision is made to take some of a facility's allocation away and give it to the remediation discharge, a $BOD_5$ to $BOD_{ult}$ ratio should be determined for the remediation discharge.

## Conclusion

The analysis shows substantial available wasteload allocation capacity for the remediation discharge to borrow from the Cluster I and, II or III facilities named above and should not adversely effect the facilities' production schedule, based on their past three years of production. It is also safe to assume that all of the dischargers in Clusters I, II and III will not be discharging more than 22%, 23%, and 31% respectively of their wasteload allocation on average based on the last three years of production. This leaves a considerable amount of assimilative capacity for the remedial discharge's use. The amount of dissolved oxygen depleted from the water column by the remediation discharge is less than 0.32 mg/l and becomes much less as the river flow increases. Therefore , the amount of $BOD_5$ discharge from the remediation sites will not have a significant impact on water quality.

A discussion needs to take place as to where the best outfall location for the remediation discharge. This analysis does not indicate approval or disapproval for any location so long as the outfall location is in the same cluster as a facility being reduced, if a facility will have its wasteload allocation reduced. Due to the low percentages of wasteload allocation used by the facilities the actual outfall location within a cluster won't effect the water quality.

***Table 1: Available Assimilative Capacity At Worst Case Scenario Conditions for Clusters I and III***

| ***Cluster I*** **Facility** | **Unused lbs/day** | **Percent Used** |
|---|---|---|
| American Tissue | 1095 | 42.8% |
| Kimberly Clark | 682 | 34.9% |
| Neenah-Menasha POTW | 2782 | 9.2% |
| Grand Chute-Menasha West | 1336 | 8.7% |
| P.H. Glatfelter | 3675 | 10.3% |
| SCA Tissue | 1118 | 25.0% |
| **Total Unused WLA** | **10,688** | |
| **Average Percent Used** | | **21.8%** |

| ***Cluster III*** **Facility** | **Unused lbs/day** | **Percent Used** |
|---|---|---|
| International Papers | 1071 | 30.2% |
| De Pere POTW | 2824 | 16.5% |
| Fort James West | 12,506 | 1.4% |
| Fort James East | 527 | 85.7% |
| Proctor & Gamble | 10,726 | 4.6% |
| Green Bay Packaging | 1882 | 14.4% |
| Green Bay POTW | 9995 | 4.9% |
| **Total Unused WLA** | **39,531** | |
| **Average Percent Used** | | **22.5%** |

| ***Cluster II*** **Facility** | **Unused lbs/day** | **Percent Used** |
|---|---|---|
| Kerwin | 1071 | 69.5% |
| Appleton POTW | 2824 | 13.2% |
| Stora Enso North America | 12,506 | 11.9% |
| Appleton Paper | 527 | 56.2% |
| Heart of the Valley POTW | 10,726 | 1.9% |
| International Papers | 1882 | 28.4% |
| **Total Unused WLA** | **29,536** | |
| **Average Percent Used** | | **30.2%** |

***Table 2: Example of Re-Allocation of Wasteload Allocation***

| **Facility** | **$BOD_5$ lbs/day** | **$BOD_5$ to $BOD_{ult}$** | **$BOD_{ult}$ lbs/day** |
|---|---|---|---|
| P.H. Glatfelter | 4017 | 1 : 1.87 | 7522 |
| American Tissue | 1462 | 1 : 5.5 | 8041 |
| Kerwin | 1000 | 1 : 3 | 3000 |
| Fort James West | 8979 | 1 : 5 | 44895 |
| Remediation Discharge | 1285 | 1 : 3* | 3855 |

* Ratio is an approximation only.

Cc: Greg Hill - WT2
Ed Lynch - RR/3
Jeff Haack - NER

# White Paper No. 8 – Habitat and Ecological Considerations as a Remedy Component for the Lower Fox River

***Response to a Review of***

## Baseline Human Health and Ecological Risk Assessment: Lower Fox River and Green Bay, Wisconsin Remedial Investigation and Feasibility Study

October 2001

***This document has been prepared by***
Wisconsin Department of Natural Resources

**December 2002**

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# ABSTRACT

During the comment period, comments were received expressing concern that the remedial activities defined in the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) would adversely impact the aquatic resources of the Lower Fox River. These commenters stated that the Proposed Plan lacked both a quantitative and qualitative assessment of the potential ecosystem damage, and that the remedial activities would result in loss of habitat. Specifically, impacts to submerged aquatic vegetation (SAV), loss of substrate material (i.e., gravel and snags), fish food sources, and decreases in fish populations were cited as adverse responses to dredging. As part of the comments to the Proposed Plan, the Appleton Papers, Inc. Panel (API Panel) submitted a report entitled *Ecosystem-Based Rehabilitation Plan – An Integrated Plan for Habitat Enhancement and Expedited Exposure Reduction in the Lower Fox River and Green Bay* (Panel Report) (The Johnson Company, 2002) in which capping was offered as a potential remedial alternative, concluding that it resulted in habitat enhancement. In response, this White Paper presents an assessment of the current habitat conditions and an analysis of potential ecosystem damage from remedial activities including an analysis of the benefits of dredging versus capping. The analyses presented here show that both dredging and capping should have minimal adverse impact on aquatic communities. However, capping, in itself, would not provide a habitat enhancement due to short-term negative environmental impacts in suppressing benthic populations. Further, cobble material used in high-flow areas would refill with silt and would not create fish breeding areas. Additional conclusions drawn from the assessment were that potential impacts to habitat would be a consideration when selecting remedial actions. And, while not a component of the remedial design, restoration would be conducted separately under the Natural Resource Damage Assessment (NRDA) settlement.

# 1 INTRODUCTION

## 1.1 PURPOSE

This White Paper considers habitat and/or fisheries-related issues associated with proposed remedy components for the Lower Fox River. Active management of approximately 2,400 acres of river bottom is being considered for the Lower Fox River by the Wisconsin Department of Natural Resources (WDNR) and the United States Environmental Protection Agency (EPA). While the WDNR and EPA's Proposed Plan (WDNR and EPA, 2001) marked those areas for dredging, a final Record of Decision may in fact be an integrated management program, combining dredging, capping, and natural attenuation to achieve management goals.

Dredging and capping are important components of assessing any remedial alternative for the Lower Fox River and Green Bay. This is reflected in the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a) and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), the Panel Report (The Johnson Company, 2002) prepared on behalf of Appleton Papers, Inc., (API) and in the response prepared on behalf of the Fox River Group (FRG) and associated companies to the RI/FS. One criticism of dredging is that removal of sediments alters the biological communities and removes the base of the food chain, as well as potential nursery habitat for juvenile fish. Opponents of capping argue that placement of artificial substrate in a depositional environment adversely effects the base of the food chain and provides little to no additional benefit to existing fish species. Clean material could and should attract benthic invertebrates and other aquatic species to utilize the area. This clean material overlays contaminated materials. Animals attracted to this new area may be exposed to contaminated materials below the surface, by borrowing or eating prey items that can burrow into the contaminated material below.

This White Paper evaluates these issues by examining the scientific literature, individual case studies, and data collected for the Lower Fox River. The objective is to realistically characterize where potential habitat impacts may occur within the River, to evaluate whether these issues have been of concern at other sites, and then to determine if there are ways to mitigate those concerns if impacts will occur.

The White Paper draws on extensive previous experience and work done by the United States Army Corps of Engineers (USACE), experience by WDNR and University of Wisconsin, Madison fisheries biologists and limnologists, and habitat maps prepared by both the National Oceanic and Atmospheric Administration (NOAA) and Exponent (1999).

This White Paper will focus on the potential for those impacts within the Operable Units (OUs) that may be impacted by remedial alternatives.

The key points contained in this report are as follows:

1. Potential impacts to habitat should be a consideration when selecting remedial actions, but restoration is not a remedial action objective (RAO).

2. Dredging and capping, both locally and nationally, has been shown to have minimal impact on aquatic communities.

3. Both dredging and capping have the potential to resuspend sediments, but the levels of resuspended solids and PCBs are lower than those naturally occurring on the Lower Fox River.

4. Benthic invertebrates are in low diversity in the Lower Fox River and, as evidenced by the case studies provided, recovery may occur quickly in depositional areas of the Lower Fox River following dredging activities.

5. Marsh habitat is an important and sparse asset on the Lower Fox River. Any remedial alternative should weigh the environmental risks from PCBs left in place to the risks of loss of habitat.

6. Fish will not be affected by any of the proposed remedial alternatives.

7. The type of habitat enhancements consistently called for by WDNR and the Proposed Plan are those that would support the diversification of the fish assemblages within the River, and the creation of more nearshore, shallow littoral habitat.

## 1.2 EFFECTS

An important issue to consider is the effect of any active sediment management operation on the associated aquatic species within the Lower Fox River. Remedial effects associated with dredging have been well studied and documented (Allen and Hardy, 1980; Clarke and Wilber, 2000; Guannel et al., 2002; Snyder, 1976; USACE, 2002). The effects examined have included numerous studies in the scientific and regulatory community ranging from resuspension, substrate and depth changes, particle settling, in-water disposal, noise (in- and above-water), chemical releases, fish entrainment in dredge equipment, and changes in habitat and community structure.

The majority of research conducted on the habitat effects of dredging has been in relation to dredged material disposal (Hirsch et al., 1978; LaSalle et al., 1991). The body of literature describing the recovery of the remaining sediment following dredging, especially in freshwater systems, is far less substantial. However, many studies discuss recovery following other types of disturbances. The effects of disturbances like dredging may be short-term or long-term depending on the nature of the impact, stream type, biotic group, and timing of the disturbance (Milner, 1994; Niemi et al., 1990; Detenbeck et al., 1992). Direct effects of dredging may include injury or mortality of benthos, fish, and wildlife, or loss of habitat (Pearson, 1984; Carline and Brynildson, 1977; Harvey and Lisle, 1998; Larson and Moehl, 1990; Armstrong et al., 1981). Substrate changes, removal of refugia (cover), and loss of in-stream and streamside vegetation may also result in indirect impacts to aquatic and aquatic-dependent organisms. Indirect effects may include reduction of abundance and diversity of benthos, fish, and wildlife, and change in habitat characteristics resulting from altered physical or chemical habitat or food sources (Yount and Niemi, 1990; Carline and Brynildson, 1977; Simpson et al., 1982). Effects to and recovery of aquatic communities following disturbance events are generally evaluated by comparing the condition of unstressed, surrounding areas to source areas.

The USACE has been concerned with documenting and identifying ways of managing the environmental effects associated with removal and capping operations since the early 1970s. Much of this research has been compiled by the USACE in a web-accessible format. The E2-D2 (Environmental Effects & Dredging and Disposal) literature database includes technical references covering a diverse range of topics related to environmental effects of dredging and dredged material disposal projects (http://www.wes.army.mil/el/e2d2/index.html). As currently configured, E2-D2 contains approximately 3,000 references.

The principal impacts that are of concern for the Lower Fox River for any active remedial alternative include

- Impacts to water column aquatic biota from sediment resuspended during dredging or capping operations;
- Impacts to benthic biota from sediment removal or capping;
- Alterations to SAV;
- Impacts to fish species during and after dredging operations; and
- Alterations to critical habitat for benthos or fish species.

# 2 CRITICAL HABITAT AND BIOTA

This section of this White Paper reviews the variables associated with recovery of aquatic habitats following disturbance events like dredging and capping, to identify and summarize site-specific studies that investigated habitat recovery following disturbance, and to apply principles derived from these studies to the specific habitat characteristics and proposed remedy of the Lower Fox River system. The Lower Fox River habitat and food web are summarized in order to consider how the habitat may recover from the effects of dredging, based on pilot studies conducted in the Lower Fox River and literature-derived scientific studies.

Each of the River reaches has been deemed a separate OU (OUs 1 through 4). An OU is a geographical area designated for the purpose of analyzing remedial actions, usually on the basis of uniform properties and characteristics throughout the OU. The River reaches and corresponding OUs are:

- **OU 1 –** Little Lake Butte des Morts;
- **OU 2 –** Appleton to Little Rapids Reach;
- **OU 3 –** Little Rapids to De Pere Reach; and
- **OU 4 –** De Pere to Green Bay Reach.

Descriptions of the aquatic and terrestrial habitats that occur in each of the four Lower Fox River OUs are included along with a review of the organisms that make up the food web within the River. The amount and type of aquatic, terrestrial, and fringe habitats present may have a direct or indirect influence on the effects of dredging and the recovery of each habitat following dredging. Different habitats recover from disturbances like dredging at different rates. Understanding important variables like the distribution of substrate types and sizes and the distribution of SAV are important parameters that influence the types of organisms that make up the benthic and aquatic communities.

## 2.1 LOWER FOX RIVER HABITAT

The Lower Fox River is the largest Green Bay tributary based on both discharge and drainage area (6,330 square miles). Many dams and locks exist in the assessment area that serve to change the functional ecology of the Lower Fox River system into a system that is more characteristic of a series of lakes and pools (WDNR, 1994). The River narrows to as little as 150 meters and widens to more than 300 meters in Little Lake Butte des Morts. Little Lake Butte des Morts (OU 1) is characterized by slower velocities and is more similar to a lentic (lake) system than any of the other three Lower Fox River OUs. OU 2, from Appleton to Little Rapids, is a narrow, channelized reach with high velocities. OU 3, from Little Rapids to the De Pere dam, and OU 4, from the De Pere dam to Green Bay, each contain a variety of faster flowing areas and slower, pooled environments.

A variety of habitats are present in the Lower Fox River and on the buffer of terrestrial vegetation adjacent to the River (i.e., riparian zone). For the purposes of this report, the habitats for each of the four OUs are characterized in terms of SAV and substrate distribution. Brief summaries are provided describing the shoreline type and terrestrial habitats adjacent to the River. Habitat information is taken from investigations conducted by Exponent in summer and fall of 1998 (Exponent, 1998), and from wetland surveys conducted by NOAA and the United States Fish and Wildlife Service (USFWS). Detail for all wetland habitat types within the Lower Fox River and Green Bay are presented in the RI (RETEC, 2002a).

### 2.1.1 Little Lake Butte des Morts – OU 1

Little Lake Butte des Morts is a wide stretch of River with a small flow gradient, yielding slower flow velocities than much of the River. It makes up approximately 900,000 square meters of habitat for fish and wildlife. Much of its shoreline is composed of riprap (53 percent) and bulkhead piling (17 percent). Natural shoreline, comprised of cover by canopy and undeveloped open areas, represents 32 percent of the total shoreline. The northwestern side of Little Lake Butte des Morts near the confluence of Mud Creek and in backwaters, coves, and tributary mouths are dominated by emergent wetlands. SAV is present in these areas at an estimated 60 percent of the total shoreline coverage. It is present in 48 percent of the open-water area of Little Lake Butte des Morts.

Approximately half of the substrate in the Little Lake Butte des Morts Reach is comprised of semi-compact sands and/or clay-type deposits. The remainder of the unit is composed of soft, aqueous, silty sediments and deposits of irregular, compact sand, gravel, and cobble. Much of the area is generally shallow; depths in the lake south of the Mud Creek confluence are generally less than 6 feet, and only achieve depths greater than 10 feet in the thalweg of the River. North of the Appleton dam, the River becomes narrower and deeper; up to 17 feet, but seldom exceeding 20 feet in overall depth. Table 1 provides summaries of the distribution of substrate types in each OU.

### TABLE 1 LOWER FOX RIVER SUBSTRATE DISTRIBUTION

| Type | Description | Little Lake Butte des Morts | Appleton to Little Rapids | Little Rapids to De Pere | De Pere to Green Bay |
|---|---|---|---|---|---|
| Type I | Soft, aqueous, silty sediments | 30 | 15 | 85 | 95 |
| Type II | Semi-compact to compact sands and/or clay | 50 | 7 | 4 | 3 |
| Type III | Compact sand, gravel, and cobble deposits | 20 | 77 | 6 | 1 |
| Type IV | Combination of Types I and II | 0 | 0 | 4 | 2 |
| Type V | Cobble and boulder-size rocks | 0 | < 1 | < 1 | 0 |

**Notes:**
Percent estimates are based on a qualitative interpretation of the preliminary side-scan sonar results.

Estimates for each OU are averaged from estimates for corresponding areas as categorized in the original habitat characterization (Exponent, 1998).

Habitat uses within Little Lake Butte des Morts are seriously impaired due to the heavy loads of silt, phosphorus, and nitrogen from Lake Winnebago. All species within this reach are affected by siltation, which reduces the fish habitat. Little Lake Butte des Morts is also affected by serious algal blooms and is considered to be a hypereutrophic lake (WDNR, 2002a).

### 2.1.2 Appleton to Little Rapids – OU 2

The River narrows at Appleton and flow velocity increases; however, several dams and locks are present. A total of 41 percent of the shoreline of the upper portion of OU 2 is developed as residential and urban/commercial. Shoreline becomes more residential below Cedars Lock and primarily agricultural for the remainder of the reach until Little Rapids. The density of maintained properties of OU 2 allows for greater deadfall and overhang in the lower stretches than in the upper stretch. Natural shoreline with undisturbed canopy dominates in undeveloped areas.

Large clusters of uninhabited islands are present in the middle portion of OU 2, near the area of the Thousand Island Conservancy. These islands provide backwater habitat, shoreline access, and an extensive lock channel system used by fish and wildlife. Tributaries are present in each stretch; however, they are most common in the lower portion of OU 2. These tributaries provide small wetlands consisting of floating and narrow-leafed emergent vegetation that account for the majority of the sparse occurrence of SAV in shallow, slower-flowing areas.

Sand, gravel, and cobble are most common in OU 2. Only smaller patches of semi-compact sands and/or clay are scattered throughout the upper and lower portions of OU 2. Very small patches of cobble and boulder and one patch of soft, aqueous, silty sediment is present in a widened section in the middle of OU 2; however, almost the entire reach is composed of sand, gravel, and cobble common to faster flowing waters.

### 2.1.3 Little Rapids to De Pere – OU 3

The River widens following the Little Rapids Lock into an area fed by numerous tributaries that provide fish and wildlife habitat along only small areas of natural shoreline. Land use is mostly agricultural and becomes more residential and urban/commercial moving downstream near De Pere. Shoreline coverage is similar to that of Little Lake Butte des Morts, comprising nearly 50 percent of the total shoreline coverage. SAV is present in low abundance.

The area immediately below the Little Rapids dam is composed of riffle runs, but quickly becomes quiescent and shallow, with depths averaging 5 to 8 feet. As the River narrows toward De Pere, the habitat becomes more channelized, but characterized by deeper water and slower flow velocities. Compact sand and gravel sediment present in the riffle area transitions to a mix of soft, aqueous, silty sediments and compact sands and clays, followed by an area of soft, aqueous, silty sediment for the remainder of the reach. Few structural attributes such as island networks, lock channels, and bridge abutments are present in OU 3, with less diverse habitat types compared to other parts of the Lower Fox River.

### 2.1.4 De Pere to Green Bay – OU 4

Virtually all of the shoreline of OU 4 is developed as industrial, commercial, or residential development. The most important characteristic of the area is the pronounced reduction in natural shoreline cover when compared to the other parts of the River. Few wetlands are present due to the urban nature of the reach. Bulkhead piling and riprap are more common in this reach than any of the other reaches. Natural shoreline constitutes only 12 percent of the total shoreline from the Mason Street Bridge to the mouth of the Lower Fox River but is slightly more common upstream to the De Pere dam.

Substrate of the River in this area is generally soft, aqueous silt, with very little cover of cobble or large rocks. A small portion of the substrate is associated with the dam riffle, comprised of compact sand, gravel, and cobble. SAV and emergent aquatic vegetation are in low density, present only in shallow coves and backwater areas. Water clarity is low. Water clarity is a function of both phytoplankton bloom and silt load in all reaches of the River. In addition, urban runoff can affect water clarity.

While the Lower Fox River widens immediately below the De Pere dam, the depths within the main channel of the River are generally greater than 10 feet of depth. Some shallow areas exist in the vicinity of the Brown County Fairgrounds and just immediately south of the Fort Howard facility. Beginning at approximately the Fort Howard facility, the River has been narrowed and channelized, with water depths now 20 to 30 feet through the navigation channel out into Green Bay.

## 2.2 FOOD WEB OF THE LOWER FOX RIVER

The Lower Fox River habitat supports a diverse community dependent on key variables such as water quality and depth, substrate distribution, and presence of SAV, among others. This section describes the habitat and groups of organisms constituting the communities present in the Lower Fox River. Furthermore, it describes the mechanisms of recolonization known for each organism group. These mechanisms are important in determining the rate at which the community and individual organisms recover following disturbance.

In order to understand the habitat issues, it is also important to understand the connections between the trophic structure present at the Site. The relationships between organisms at the base of the food chain and the fish and other organisms that feed upon them were defined by WDNR biologists (WDNR, 2001) for the RI/FS. The important consideration for habitat effects from dredging or capping is that the Lower Fox River functions as a pelagic food chain; that is, the food chain rests upon organisms within the water column and not on organisms living in the sediments. The food chain for the mouth of Lake Winnebago to the De Pere dam is shown on Figure 1. A second model was developed for below the De Pere dam through Green Bay Zone 2 (Figure 2). The De Pere dam restricts movement of Green Bay alewife and rainbow smelt further up the Lower Fox River. The only differences in conceptual model receptor species between these three models are the fish. The organisms comprising these communities and their respective mechanisms of recovery are summarized below.

**Figure 1  Food Web Model for the Lower Fox River from Little Lake Butte des Morts to the De Pere Dam**

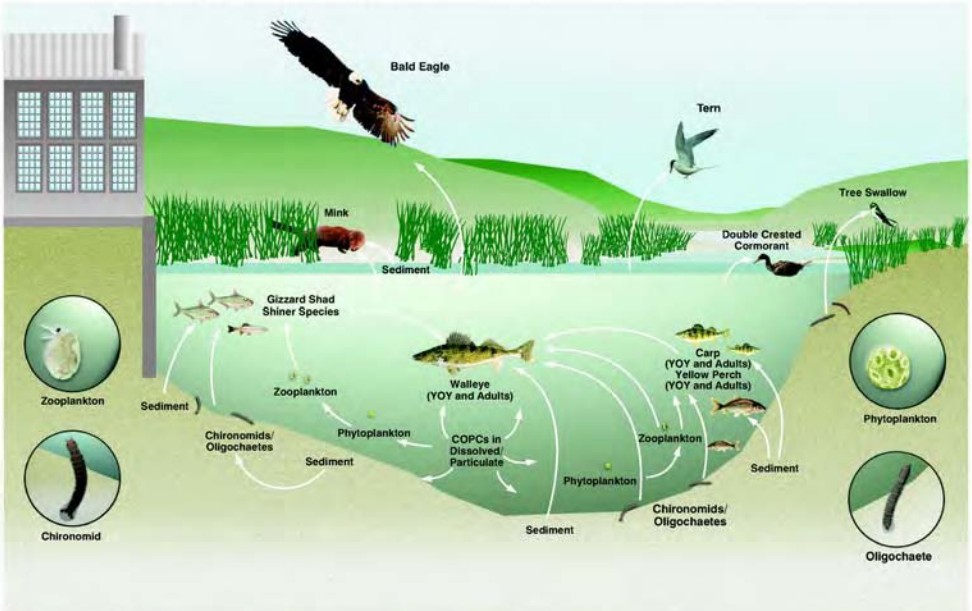


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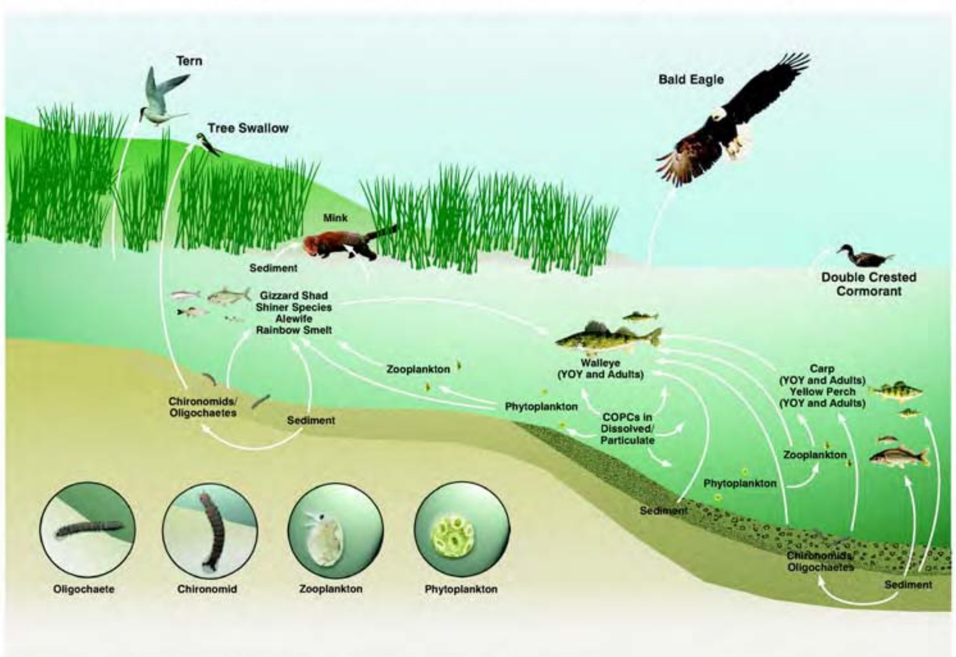
**Figure 2  Food Web Model for the De Pere Dam through Green Bay Zone 2**

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### 2.2.1 Phytoplankton and Zooplankton

Pelagic communities inhabiting the water column include both phytoplankton and zooplankton. Throughout the Lower Fox River and Green Bay, the food chain rests upon phytoplankton production. Phytoplankton are small uni- or multi-cellular algae and form the base of the pelagic food chain. They are common throughout all reaches of the Lower Fox River and are consumed by both fish and some benthic and epibenthic invertebrates. Phytoplankton presence can be limited by nutrient and light availability, but are typically widespread in any aquatic environment (Wetzel, 1983). Phytoplankton thrive on nutrients in the water column that are present in the Lower Fox River in part because of their association with suspended sediments.

Primary producers in the water column (phytoplankton) and detritus, or decomposing organic matter, represent the first level of trophic structure. The next trophic level, primary consumers, includes zooplankton and benthic infauna that feed directly on the phytoplankton or detritus/organic carbon within the sediment. Depending on zooplankton population levels, phytoplankton levels can either be limited or overabundant. If phytoplankton become overabundant (i.e., they are not sufficiently grazed by zooplankton) then they eventually die, settle to the sediment surface, and, as detritus, become part of the benthic food chain. Decomposition in organically rich sediments can lead to oxygen-depleted (anoxic) sediment and overlying water.

As noted previously, the entire Lower Fox River system and large parts of Green Bay are considered to be eutrophic. In the late summer, thick mats of algae (*Chladophora* spp.) cover parts of Little Lake Butte des Morts, and result in depressed oxygen and poor water conditions that have resulted in frequent fish mortalities. Phytoplankton die-offs are also implicated as one causal factor in the annual avian botulism die-offs (WDNR, 2002a).

Relative levels of eutrophication are quantified by the Trophic State Index (TSI); a TSI greater than 50 is considered to be a highly eutrophic system. While there are no TSI data specific to Little Lake Butte des Morts, TSI data for Lake Winnebago at Menasha indicate that the TSIs are always above 50, and are as high as 77 (WDNR, 2002b). The southern part of Green Bay, including the section north of the De Pere dam, is also considered to be eutrophic. The Lower Fox River alone contributes over 75 percent of the total phosphorus load to Green Bay (Auer et al., 1985). In Lake Winnebago, the phytoplankton community appears to be nitrogen-limited in summer and is probably never phosphorus-limited (Gustin, 1995). About 40 percent of the annual inputs of phosphorus to the sediments are recycled. The intensity of the release rate of phosphorus depends on the rate of mineralization and the occurrence of lake-wide physical mixing events.

### 2.2.2 Emergent and Submerged Aquatic Vegetation (SAV)

There are two types of important aquatic vegetation in the Lower Fox River: SAV and emergent vegetation. SAV is a term used to describe rooted macrophytes typically found in shallow, nearshore waters that are wholly within the water. Examples of these plants include the common pondweed (*Potamogeton* spp.), water lilies (*Nyphaea* spp.), or Eurasian milfoil (*Myriophyllum spicatum*). Emergent vegetation are rooted within the River, but have a portion of their plant body above the water. Examples of emergent vegetation include cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.). These plants form complex marsh systems that provide critical spawning, nursery, feeding, and/or cover habitat for many species of fish (Brazner and Magnuson, 1994). Typical emergent plants within the marshes of the Lower Fox River and Green Bay include bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), arrowheads (*Sagittaria* spp.) and sedges (*Carex* spp.). Common submerged and floating species include *Potamogeton* spp. and water lilies (*Nyphae odorata* and *Nuphar variegatum*). These nearshore wetland habitats support a diverse fish assemblage that includes yellow perch, shiners, northern pike, bluegills, and largemouth bass. Water clarity and depth are limiting factors for the establishment of rooted aquatic macrophytes (Szymanski, 2000), and within the Lower Fox River system these are generally limited to areas that have less than 2 feet of water depth.

Freshwater marshes have also been identified as one of several critically imperiled communities in the Great Lakes (Nature Conservancy, 1994), and their maintenance has been adapted by the Great Lakes Remedial Action Plan as a central part of habitat restoration (Great Lakes RAP, 1996) play a pivotal role in the aquatic ecosystem of the Great Lakes, storing and cycling nutrients and organic material from the land into the aquatic food web. They sustain large numbers of common or regionally rare bird, mammal, reptile, and invertebrate species, including many land-based species that feed from the highly productive marshes. Most of the lakes' fish species depend upon them for some portion of their life cycles (Whillans, 1990), and large populations of migratory birds rely on them for staging and feeding areas.

Within the Lower Fox River, there are very few acres of rooted SAV marshes. As documented in the RI, approximately 825 acres of SAV are present in the Lower Fox River. Of these, 642 acres were present within Little Lake Butte des Morts, most associated with the Stroebe Island Marsh and other backwater wetlands. Within the Appleton to Little Rapids Reach (OU 2), there are 153 acres; most being associated with the Thousand Islands wetlands. There are 64 acres downstream of the Rapide Croche dam, and only 20 acres downstream of the De Pere dam (Exponent, 1998).

Reports of SAV in Little Lake Butte des Morts included descriptions of various species of pondweeds (*Potamogeton* spp.), waterweed (*Elodea nuttallii*), eel-grass or water celery (*Vallisneria americana*), and the water lilies (*Nyphaea* spp. and *Nuphar variegatum*). These species are located on the shallow edges and backwater coves. Large cattail stands (*Typha* spp.) are also identified near Stroebe Island where Mud Creek enters the Lower Fox River. The last remnant of northern pike spawning marsh is located along inside (west side) of Stroebe Island. Northern pike is an important predator species and WDNR has indicated that this spawning marsh should be protected from future dredging or fill (WDNR, 2002a).

What is not clearly identified in these reports is that the most prevalent SAV within Little Lake Butte des Morts is the undesired exotic Eurasian water milfoil (*Myriophyllum spicatum*). This introduced species annually forms huge monoculture stands with vast mats of surface foliage that shade out native aquatic plants and reduce oxygen content within the water. It is an opportunistic species that prefers lakes having a high load of nitrogen and phosphorous, which is also typical of Little Lake Butte des Morts.

There is a considerable body of literature that supports the position that the Eurasian water milfoil provides relatively little value as a habitat or food source for the native plants it replaces (USGS, 2002). The United States Geological Survey (USGS) scientific literature review determined that while milfoil will support epibenthic organisms, at high densities it has a low abundance and diversity of invertebrates, organisms that serve as fish food (Keast, 1984). The characteristics of Eurasian water milfoil's overabundant growth negate any short-term benefits it may provide fish in healthy waters. Dense cover allows high survival rates of young fish; however, larger predator fish lose foraging space and are less efficient at obtaining their prey (Lillie and Budd, 1992; Engel, 1995). Madsen et al. (1995) found growth and vigor of a warm-water fishery reduced by dense Eurasian water milfoil cover. The growth and senescence of thick vegetation depletes dissolved oxygen levels and degrades water quality (Honnell et al., 1992; Engel, 1995).

### 2.2.3 Benthic Organisms

The benthic macroinvertebrates in the Lower Fox River include adult and larval insects, mollusks, crustaceans, and worms. Given the predominance of fine-grained silt/clay sediments in the River, the predominant species are sediment-dwelling and burrow directly into the substrate for most of their life cycle. The benthic macroinvertebrate community plays an important role in ecosystem functions such as nutrient cycling and organic matter processing, and is a food resource for the benthic and pelagic fish communities.

Much of the benthic community surveys in the Lower Fox River sediment have shown low taxa richness and diversity with chironomids (midge larvae, Family Chironomidae) and oligochaetes (worms, Class Oligochaeta) dominating (IPS, 1993a, 1993b, 2000a, 2000b, 2000c; WDNR, 1996). Oligochaetes and chironomids are thought to be tolerant of organic enrichment and/or degraded habitats, whereas other species are less tolerant of enriched/degraded habitats (EPA, 1990).

Species of oligochaetes generally feed on decaying organic matter, including fine detritus, algae, and other microorganisms. The primary food for chironomids is planktonic algae and detritus. Chironomids and oligochaetes are normally found in greatest abundance in soft sediment deposits in pools, runs of streams, profundal areas and littoral areas of lakes with soft bottoms, and harbor or bay areas where stream-transported sediments have been deposited (Wetzel, 1983). River rock and riffle areas are not preferred habitat. Thus, within the Lower Fox River, removal of PCB-contaminated sediment would largely affect only these benthic communities.

Samples at some stations in the River have shown increased numbers of benthic invertebrates and increased diversity. For example, samples collected from Deposit POG in Little Lake Butte des Morts in 1994 were principally dominated by chironomids and oligochaetes, but also showed the presence of flatworms, sow bugs, amphipods (*Hyallela azteca*), clams (*Pisidium* spp.), and physid snails that had previously not been observed. However, this increase was only observed within Little Lake Butte des Morts; the remaining stations through the River remain low in diversity (IPS, 1994). The mayfly *Hexagenia bilineata* has been found below the De Pere dam, suggesting improvement in overall water quality (Cochran, 1992). However, these have only persisted at very low numbers, suggesting that recolonization is still limited by poor environmental conditions (Cochran and Kinziger, 1997).

The recovery of benthic invertebrates is complex due to differences in body size, reproductive techniques, mobility, and life span (Steinman and McIntire, 1990). Methods of recolonization usually depend on the types of migration sources. Four principal sources and mechanisms for stream benthos have been identified: (1) downstream migration or drift; (2) upstream migration; (3) vertical migration from within the substrate; and (4) aerial sources (Williams and Hynes, 1976; Williams, 1981). Not all migration sources are available in every aquatic system, but one or more are almost always present.

In general, downstream drift is typically the most important recovery mechanism of the benthos (Niemi et al., 1990; Minshall and Peterson, 1985). It is a particularly important relocating mechanism following disturbance for invertebrates that do not move far under their own power, such as relatively sedentary chironomids (Mackay, 1992). Chironomids are some of the earliest colonizers in experiments with newly placed bare substrates in streams (Waters, 1964; Gray and Fisher, 1981), in part because of their prominence in the drift (Waters, 1972).

Aerial colonization represents a major source for recovery, especially for large-scale disturbances like channel relocation. When other migration sources are unavailable, aerial colonization by invertebrates emerging from immature aquatic life stages can be very important. Chironomids, for example, have one or more generations per year in a population, maturing from egg, larva, and pupa aquatic life stages. They have been found to recolonize disturbed systems quickly thanks to their high dispersal abilities afforded by small wings and relatively light weight (Brundin, 1967). Other emergent invertebrates, like most Ephemeroptera (mayflies), Trichoptera (caddisflies), and many Plecoptera (stoneflies) are prevalent in the drift but considered weak fliers, while Odonata (dragonflies and damselflies), some Coleoptera (beetles), and Hemiptera (bugs) are good fliers (Williams, 1981). Molluscs are typically one of the last taxa to recover following disturbances (Wallace, 1990), presumably as a result of poor dispersal mechanisms.

### 2.2.4 Fish Species and Habitat Preferences

Fish in the Lower Fox River are largely dependent on water column organisms for food – a pelagic- rather than benthic-based food web (WDNR, 2001). Most secondary fish consumers depend on phytoplankton and zooplankton, and higher consumers rely on other fish. Multiple fish population surveys of the Lower Fox River have been completed to date. Fish catch results from these studies are summarized in the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA), but include at least 43 different fish species upstream of the De Pere dam (RETEC, 2002c). Twenty-four (24) were game fish and 19 species were non-game fish (as defined by state statute). This section touches briefly on the general composition of fish present in the Lower Fox River, and focuses more specifically on four groups of fish: carp, centrarchids, perch, and walleye.

### GENERAL FISH DISTRIBUTIONS WITHIN THE RIVER

Population results for Little Lake Butte des Morts indicate that game fish typically comprise about 30 to 40 percent of the fish captured (RETEC, 2002c). Yellow perch, walleye, white bass, and bullheads have all been the dominant game fish species at one point or another. Carp (a non-game fish) was the most prevalent fish observed in the Lower Fox River upstream of the De Pere dam. Carp typically account for 50 to 90 percent of non-game fish and approximately 50 to 60 percent of all fish captured in the surveys.

In the De Pere to Green Bay Reach, game fish account for 70 to 90 percent of the total captured fish population. The dominant game fish typically include yellow perch, one of the primary commercial species in the Bay, as well as walleye, white bass, and white perch. Walleye is another game fish that generally comprises more than 10 percent of the total fish population (RETEC, 2002c). Non-game fish below the De Pere dam are predominantly carp, white sucker, drum, and quillback.

Fish species are generally well distributed and use all areas of the last reach of the River (OU 4). Depending on the season and location of food items, all of the six named species can be found nearer the De Pere dam (OU 4), or within the channelized portion (OU 4). Adult walleye, as an example, are frequently found associated with structure in OU 4 and pursue gizzard shad that can be found in all areas of the River. In fact, most of the seasoned anglers attempting to catch larger walleye focus on the shipping channel associated with submerged structures even during the spawning period because many large females can be found at these locations. Many of these sites are found in the downstream sections of OU 4. While it is true that the highest fishing pressure for walleye occurs during the spawning period, anglers seek walleye at other times of the year, particularly during late summer and fall. During the summer and fall, the downriver areas can be especially productive. Furthermore, flathead catfish are sought throughout the summer months and anglers frequently fish from shore for this species along the walkway in downtown Green Bay. White bass and white perch are particularly attracted to the many warm-water discharges that can be found in OU 4, especially during early spring and late fall.

### CARP

Carp are a bottom-dwelling species in the family Cyprinidae. They tolerate turbidity, low dissolved oxygen, pollution, and rapid temperature changes better than most any other fish in North America (Becker, 1983). Although they are tolerant of a wide range of conditions, they prefer shallow lakes and streams that have abundant aquatic vegetation and are warm (Becker, 1983). Young-of-the-year (YOY) carp diets consist of phytoplankton and zooplankton, while adult carp consume chironomids, oligochaetes, and zooplankton (Scott and Crossman, 1973; Weber and Otis, 1984; Carlander, 1997).

An investigation of spawning carp in Lake Winnebago and nearby lakes determined that carp prefer to spawn in areas of shallow vegetated waters 0.15 to 1.2 meters deep (Weber and Otis, 1984). These preferences have been supported by other authors (Becker, 1983; Scott and Crossman, 1973). Carp eggs attach themselves to underwater vegetation, debris, or any other object to which the egg will adhere (USFWS, 1982). Spawning over areas with dense vegetation will increase the success of reproduction. Young carp also strongly associate with vegetation as protective cover in 15- to 30-cm deep water (Weber and Otis, 1984).

#### *CENTRARCHIDS*

The sunfish (Centrachidae) are an important family of game fish, which include the bluegill (*Lepomis macrochirus*), pumpkinseed, (*Lepomis gibbosus*), smallmouth bass (*Micropterus dolomieui*) and the largemouth bass (*Micropterus salmoides*). As documented in the RI, throughout the Lower Fox River these species are poorly represented in the fish community (RETEC, 2002a). Only smallmouth bass, and black crappie (*Pomoxis nigromaculatus*) are taken in any significant numbers in any of the River reaches.

The limiting factor for centrarchid production in the River is the general lack of rooted aquatic macrophyte beds that provide early life-stage habitat (Becker, 1983; Lychwick, 2002). The Green Bay RAP advocated for improved habitat in the form of extensive areas of rooted aquatics, indicating the importance of this type of habitat to the River and Bay. Within Little Lake Butte des Morts, the marsh areas surrounding Stroebe Island support centrarchids.

#### *YELLOW PERCH*

Yellow perch and walleye are members of the perch family (Percidae). Yellow perch prefer shoreline areas with sand, gravel, or muddy sediments, modest to moderate amount of rooted aquatic vegetation, and water depths of less than 10 meters in clear lakes (Becker, 1983; Scott and Crossman, 1973; USFWS, 1983). Yellow perch (YOY and adults) are highly associated with complex macrophyte beds (Weaver et al., 1997). Perch consume phytoplankton and zooplankton for food (Scott and Crossman, 1973; Weber and Otis, 1984; Exponent, 1999; Carlander, 1997).

Yellow perch spawn after ice-out in April or early May. During spawning, eggs are usually deposited in sheltered areas and are frequently draped over emergent and submerged vegetation or submerged brush in water depths of 0.6 to 3 meters. Rocks, sand, or gravel may be used when submerged vegetation is not available (USFWS, 1983). They may travel long distances during migration. Lake Winnebago perch may swim from 48 to 81 km up the Fox River before they reach suitable spawning habitat (Becker, 1983).

#### *WALLEYE*

Walleye are tolerant of a range of environmental conditions, particularly turbidity and low light, but less tolerant to low oxygen levels. As adults, they prefer quiet waters over sand, gravel, and mud substrates (Becker, 1983). Generally resting in deep, dark waters during the day, they migrate to rocky shoals and weed beds to feed at night. Walleye may become active during the day if it is cloudy or the waters are turbid (Becker, 1983). YOY fish can be found near the sediments in 6 to 10 meters of water (Scott and Crossman, 1973), but are present in surface waters up to lengths of 35 mm (WDNR, 1970). Schooling is common during feeding and spawning.

YOY are believed to eat mainly phytoplankton, including diatoms and blue-green algae (RETEC, 2002c). Juvenile walleye begin to feed on fish, including alewife and yellow perch. The diet of older walleye is dominated by prey fish. When prey fish are less abundant, the walleye will feed on benthic invertebrates (RETEC, 2002c).

The walleye fishery is particularly well established throughout the Fox River (Becker, 1983) basins. Walleye will spawn in flooded marsh areas adjacent to the River. The most important attribute of these marsh areas is to have inlets and outlets which provide a continuous flow of water over the spawning area (Becker, 1983). On lakes with inlet waterways, spawning occurs in inlet streams on gravel bottoms. In some places, walleyes spawn on flooded wetland vegetation (Becker, 1983). Preferred spawning habitat are shallow shoreline areas, shoals, riffles, and dam faces with rocky substrate and good water circulation from wave action and currents (USFWS, 1984). In lakes with rocky shorelines, the rocky, wave-washed shallows are the primary spawning grounds.

A wide variety of bottom substrates already exists in the Lower Fox River. Areas of cobble, gravel, sand, and soft substrate are found throughout the River. A wide range of species are currently effectively using available habitats. Spawning habitat may be limited to some extent for walleye and smallmouth bass in the Lower Fox River but both are reproducing in the River, with walleye being fairly successful. Walleye in the Lower Fox River and Green Bay prefer to spawn over large gravel and cobble with the greatest success occurring over 2- to 6-inch material. This material was successfully employed by the WDNR in construction of walleye spawning enhancement areas in the River below the De Pere dam.

# 3 ENVIRONMENTAL EFFECTS OF IN-WATER REMEDIAL ACTIONS

As discussed in the introductory section, effects on aquatic organisms from remedial actions for dredging and capping have been well studied and documented (Allen and Hardy, 1980; Clarke and Wilber, 2000; Guannel et al., 2002; Snyder, 1976; USACE, 2002). The effects examined have included numerous studies in the scientific and regulatory community ranging from resuspension, substrate and depth changes, particle settling, in-water disposal, noise (in- and above-water), chemical releases, fish entrainment in dredge equipment, and changes in habitat and community structure. Capping-induced changes can be similar, if one considers the effects of change in substrate type, changes in bottom elevation, and burial of benthic species. Chemical releases of contaminants during dredging are also possible from resuspension of fine-grained material, advective releases of porewater during native sediment compression, or major release during shear failure of underlying sediments during placement of heavier, overburdening cap sediments.

Aquatic disturbances produce changes in benthic and aquatic community structure that can persist for a few weeks to many decades (Detenbeck et al., 1992; Niemi et al., 1990). The rate of succession, or community changes that occur at a site following a disturbance, is influenced by many factors, including the physical habitat and size of the disturbed area. Organisms directly impacted by physical habitat changes are periphyton (attached algae), phytoplankton, vegetation, benthic macroinvertebrates, and fish.

While all of the impacts discussed above can and have occurred at other sites, the principal impacts that are of concern for the Lower Fox River are thought to be:

- Impacts to water column aquatic biota from sediment resuspended during dredging or capping operations;
- Changes to benthic biota from sediment removal or capping;
- Alterations to SAV; and
- Impacts to fish species during and after dredging operations.

This section examines the general scientific literature and case studies on effects from removal actions and capping.

## 3.1 ENVIRONMENTAL EFFECTS OF RESUSPENSION

The biological responses of aquatic organisms to dredging resuspension has recently been very well reviewed in three separate papers; Guannel et al. (2002) Clarke and Wilber (2000), and Herbich (2000). Rather than try to re-create that information here, only the salient information relative to the Lower Fox River is presented in this section. The reader is referred to those articles for details.

The effects of total suspended solids (TSS) on aquatic biota have been studied for a wide variety of marine and freshwater organisms. The general conclusion of those studies is that significant adverse impacts are not associated with typical dredging projects of uncontaminated materials, although some localized effects can occur at higher resuspended concentrations (Guannel et al., 2002). Those authors concluded that resuspended sediment concentrations caused by natural phenomena (floods, storms, winds, etc.) are often higher and of longer duration than those caused by dredging. Table 2 shows TSS associated with typical storm event flows at other sites, relative to TSS from storm events and dredging resuspension on the Lower Fox River. This is well documented in monitoring of the pilot dredging projects as well, where pre-dredging TSS measurements were more than double the levels observed during dredging (FRRAT, 2000). TSS concentrations in mg/L for demonstration projects on the Lower Fox River, as well as for other more typical concentrations at other projects is presented in Table 3, as reviewed by Guannel et al. (2002).

### TABLE 2 TSS CONCENTRATIONS DUE TO NATURAL PHENOMENA ON THE FOX RIVER AND AS REVIEWED BY GUANNEL ET AL., 2002

| Location | Maximum Resuspension Value (mg/L) |
|---|---|
| Fox River (WDNR, 1995) | 357 |
| San Francisco Bay | 100–200 (tides) |
| Indian River Bay, Delaware | 570.0 |
| Chesapeake Bay | 600.0 |
| Bay of Fundy | 3,000.0 |
| Chesapeake Bay | 10,000 (hurricane) |
| False Bay, Washington | 10,000.0 |

## TABLE 3 EXAMPLES OF TSS CONCENTRATIONS FOR DREDGES ON LOWER FOX RIVER DEMONSTRATION PROJECTS AND AS REVIEWED BY GUANNEL ET AL., 2002

| Location | Background Concentrations (mg/L) | Maximum of Reported Mean Concentrations (mg/L) |
|---|---|---|
| ***Cutterhead Dredge*** | | |
| Lower Fox River Deposit N Demonstration | 24–56 | 58.0 |
| Lower Fox River SMU 56/57 | 28–33 | 65.0 |
| Corpus Christi Channel | 39–209 | Up to 580 |
| Upper Mississippi | 170.5 | ~170.5 |
| Portland Harbor | No changes between background and dredge conditions | |
| San Francisco Bay, California | 38–153 | ~100.0 |
| Mobile Bay Ship Channel, Alabama | 25–30 | 125.0 |
| ***Clamshell Dredge*** | | |
| San Francisco Bay, California | 40.0 | 30–90 |
| Long Beach Harbor Pier F | NA | 28.0 |
| Long Beach Harbor Pier B | NA | 1,092.0 |
| Los Angeles River Estuary Dredging Pilot Study* | 2.0 | 11.0 |
| Los Angeles River Estuary Dredging Pilot Study* | 7.5 | 9.3 |

**Note:**
* Data not yet published.

Resuspension of contaminated sediments on aquatic biota has been more difficult to assess. PCBs at the levels reported in the two demonstration projects on the Lower Fox River will not have an immediate, acute effect on the aquatic organisms. The Risk Assessment for the Lower Fox River thoroughly documents the levels of PCBs that are acute or chronically toxic to aquatic biota. The monitoring conducted during the pilot dredging projects demonstrated that even remediation at the most highly contaminated site in the River, PCB concentration did not approach these levels nor were they very different than PCB concentrations that have been observed in the water column absent dredging activity.

## 3.2 ENVIRONMENTAL EFFECTS ON BIOTA, FISH, AND SAV DURING REMOVAL ACTIONS

Sections 3.2 and 3.3 describe case studies that examine the effects and recovery of aquatic and benthic communities following disturbance events. The majority of the studies document dredging and capping events; however, other events like severe scour and channel relocation are briefly discussed. The studies have been completed to investigate the mechanisms influencing recolonization of benthic invertebrates and fish, although studies of aquatic vegetation, epibenthic invertebrates, plankton, and periphyton have also been completed.

### 3.2.1 Removal Actions

#### *DEPOSIT N, LOWER FOX RIVER WISCONSIN (FOTH AND VAN DYKE, 2000)*

A demonstration removal action of 11,000 cubic yards (cy) was initiated at Deposit N in 1998 and completed in the fall of 1999. Water depths at the location were generally 8 feet deep, with an average sediment thickness prior to removal of 2 to 3 feet (Foth and Van Dyke, 2000). Given that Deposit N lay over bedrock material and the project specification was to dredge to a depth immediately above the bedrock (approximately 6 inches), a marker exists against which to evaluate future sediment accumulation.

Sampling was conducted in July 2002 to determine: (1) the depth of material that had reaccumulated over the bedrock (i.e., original cut), (2) the surface concentrations of PCBs, and (3) the benthic infaunal communities in place 3 years after cessation of dredging.

Throughout Deposit N, there has been very little sediment accumulation. Samples were collected at stations S-5 and S-13, which were previously sampled in 1997 pre-dredging. At S-5 there was a total depth of sediment of approximately 10 inches, but S-13 had courser-grained material closer to the shore wall. Poling conducted through the rest of the site showed that with the exception of the western lobe nearer to S-5, there is very little additional accumulation. Sixty soundings were taken, and on average there is still only approximately 6 inches of sediment over most of the deposit.

#### *SMU 56/57, LOWER FOX RIVER (IPS, 2000A, 2000B, 2000C)*

The Sediment Management Unit (SMU) 56/57 demonstration project was conducted over two seasons and completed in the fall of 2000. Approximately 31,000 cy of dredged material was removed from SMU 56/57 in 1999. Grain size and benthic community were investigated the summer prior to dredging and at 3 and 9 months following termination of the 1999 dredging activity. Additional samples were collected in July of 2002. Three samples at water depths prior to dredging to 5 feet, between 5 and 10 feet, and greater than 10 feet from each of two transects were collected for all three surveys. Post-dredging surveys returned to each of these stations and two additional stations were established following dredging. Upon completion of the dredging operations, a sand cap was placed at the bottom of the dredge hole to act as a marker for future sampling.

Pre-dredging grain size distributions for each station at SMU 56/57 are contained in Table 4. Substrate was predominantly silt at four stations and sand at the other two stations. Three months following dredging, substrate changed to silt from sand at one station, but remained similar to pre-dredging distributions. The amount of clay remaining in exposed substrate following dredging increased at each station, but fractions of silt tended to be greater in the 9-month samples. Nine months following dredging, substrate changed to either silty clay or clayey silt. In the July 2002 sampling, a total of 5 feet of sediment had accumulated over the top of the placed sand cap layer. Total PCB concentrations in those samples are not available at this time.

## TABLE 4 GRAIN SIZE DISTRIBUTION (PERCENT) AT SMU 56/57

| | Transect 1 | | | Transect 2 | | | Transect A | Transect B |
|---|---|---|---|---|---|---|---|---|
| | Position 1 | Position 2 | Position 3 | Position 1 | Position 2 | Position 3 | | |
| Water Depth: | 0–5 ft | 5–10 ft | > 10 ft | 0–5 ft | 5–10 ft | > 10 ft | 5–10 ft | 5–10 ft |
| ***August 27, 1999*** | | | | | | | | |
| Sand | 72.5 | 34.6 | 34.3 | 75 | 25.4 | 35 | — | — |
| Silt | 15 | 49 | 51.4 | 12.5 | 58 | 50 | — | — |
| Clay | 12.5 | 16.4 | 14.3 | 12.5 | 16.6 | 15 | — | — |
| Total Fines | 27.5 | 65.4 | 65.7 | 25 | 74.6 | 65 | — | — |
| Organic Material | 14.4 | 15.4 | 12.8 | 18.7 | 11.9 | 10.7 | — | — |
| ***March 6, 2000*** | | | | | | | | |
| Sand | 67.5 | 27.5 | 26 | 37.5 | 30 | 27.5 | 27.5 | 35 |
| Silt | 17.5 | 40 | 41.4 | 37.5 | 37.5 | 40 | 42.5 | 37.5 |
| Clay | 15 | 32.5 | 32.5 | 25 | 32.5 | 32.5 | 30 | 27.5 |
| Total Fines | 32.5 | 72.5 | 73.9 | 62.5 | 70 | 72.5 | 72.5 | 65 |
| Organic Material | 30.3 | 14.2 | 14.3 | 12.6 | 11.8 | 12.4 | 14.4 | 12.7 |
| ***August 3, 2000*** | | | | | | | | |
| Sand | 25 | 30 | 17.5 | 30 | 27.5 | 27.5 | 25 | 27.5 |
| Silt | 47.5 | 30 | 45 | 35 | 35 | 30 | 40 | 40 |
| Clay | 27.5 | 40 | 37.5 | 35 | 37.5 | 40 | 35 | 32.5 |
| Total Fines | 75 | 70 | 82.5 | 70 | 72.5 | 70 | 75 | 72.5 |
| Organic Material | 22.4 | 14.6 | 14.4 | 14.3 | 12.3 | 15.5 | 14.5 | 13.5 |

Pre- and post-benthic invertebrate abundances for each station at SMU 56/57 are listed in Table 5. Oligochaetes and chironomids dominated benthic samples before and after dredging. Before dredging, abundances averaged 745 organisms/square foot (organisms/$ft^2$). Oligochaetes and chironomids comprised 84 and 15 percent of the total population, respectively. Three months following dredging, abundances were higher, averaging 1,035 organisms/$ft^2$, with oligochaetes accounting for 91 percent of the population. Nine months following dredging, abundances were 374 organisms/$ft^2$, with oligochaetes accounting for 94 percent. Abundances increased in several stations from the 3-month sampling, but were more similar to pre-dredging levels than 3-month levels.

Abundance recovered to greater than pre-dredge levels 3 months following dredging, but likely represented initial opportunistic colonizers that drifted into site post-removal. The sudden increases in oligochaete abundance and relatively stable chironomid abundance following dredging indicate that despite changes from sandy and silty sediment to silty and clayey sediment, recolonization occurred in as little as 3 months with similar diversity. Within 9 months, the species composition and abundances reflected the pre-dredging conditions.

## TABLE 5 BENTHIC INVERTEBRATES AT SMU 56/57

| | Transect 1 | | | Transect 2 | | | Transect A | Transect B | Average per Station | | Percent Group |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Depth:** | **Position 1 0–5 ft** | **Position 2 5–10 ft** | **Position 3 > 10 ft** | **Position 1 0–5 ft** | **Position 2 5–10 ft** | **Position 3 > 10 ft** | **5–10 ft** | **5–10 ft** | | | |
| ***August 27, 1999*** | | | | | | | | | | | |
| Oligochaeta | 1,112 | 1,368 | 536 | 400 | 166.7 | 153.3 | — | — | 622.666667 | 0.83515894 | 84 |
| Diptera | | | | | | | | | | | |
| Chironomidae | 176 | 193.3 | 114 | 56 | 60 | 50.7 | — | — | 108.333333 | 0.14530335 | 15 |
| Amphipoda | | | | | | | | | | | |
| Family Gammaridae | 2 | 0 | 0 | 0 | 0 | 0 | — | — | 0.33333333 | | |
| Gastropoda | | | | | | | | | | | |
| Family Pleuroceridae | 0.7 | 0 | 0 | 8 | 0 | 0 | — | — | 1.45 | | |
| Bivalvia | 64 | 0 | 0 | 0 | 0.7 | 0 | — | — | 10.7833333 | | |
| Nematoda | 0 | 0 | 8 | 0 | 0 | 2.7 | — | — | 1.78333333 | | |
| Hirudinea | 0 | 0 | 0 | 0 | 1.3 | 0 | — | — | 0.21666667 | | |
| **Total** | **1,354.7** | **1,561.3** | **658** | **464** | **228.7** | **206.7** | **—** | **—** | **745.566667** | | |
| ***March 6, 2000*** | | | | | | | | | | | |
| Oligochaeta | 1,256 | 132 | 3,488 | 984 | 834 | 604 | 34.7 | 228 | 945.0875 | 0.91286342 | 91 |
| Diptera | | | | | | | | | | | |
| Chironomidae | 250 | 9.3 | 193 | 56 | 119.3 | 48 | 16 | 28 | 89.95 | 0.08688303 | 9 |
| Amphipoda | | | | | | | | | | | |
| Family Gammaridae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Gastropoda | | | | | | | | | | | |
| Family Pleuroceridae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Bivalvia | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0875 | | |
| Nematoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Hirudinea | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0875 | | |
| Turbellaria | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0875 | | |
| **Total** | **1,507.4** | **142** | **3,681** | **1,040** | **953.3** | **652** | **50.7** | **256** | **1,035.3** | | |
| ***August 3, 2000*** | | | | | | | | | | | |
| Oligochaeta | 225.3 | 688 | 116 | 158 | 332 | 54.7 | 482 | 722.7 | 347.3375 | 0.92833757 | 93 |
| Diptera | | | | | | | | | | | |
| Chironomidae | 51.3 | 42 | 0.7 | 8.7 | 30 | 0.7 | 31.3 | 27.3 | 24 | 0.0641454 | 6 |
| Amphipoda | | | | | | | | | | | |
| Family Gammaridae | 0 | 0 | 0 | 1.3 | 0 | 0.7 | 0 | 0 | 0.25 | | |
| Gastropoda | | | | | | | | | | | |
| Family Pleuroceridae | 0 | 1.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1625 | | |
| Bivalvia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Nematoda | 0 | 0 | 8 | 1.3 | 0 | 1.3 | 3.3 | 4 | 2.2375 | | |
| Hirudinea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Nematomorpha | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 | 0 | 0.1625 | | |
| Horsehair, Gordian worms | 276.6 | 731.3 | 124.7 | 169.3 | 362 | 57.4 | 517.9 | 754 | 374.15 | | |

### WISCONSIN SPRING PONDS (CARLINE AND BRYNILDSON, 1977)

Two spring-fed ponds, Krause and Sunshine Springs, were dredged with a hydraulic dredge to remove organic sediments and restore or enhance sport fisheries for brook trout (*Salvelinus fontinalis*) by increasing water depth and removing aquatic macrophytes. The pond was studied for 2 years before dredging and 4 to 5 years afterwards (1967–1975). The ponds were 0.3 and 0.4 hectares in surface area. Prior to dredging, beds of *Chara*, also known as skunkweed, an invasive type of SAV, covered nearly 60 percent of the pond bottom. Densities of major benthic taxa before and after dredging are shown in Table 6. Chironomids were the dominant organisms and oligochaetes accounted for about 4 percent of all organisms.

### TABLE 6 COMPARISONS OF MEAN ANNUAL DENSITIES OF MAJOR BENTHIC TAXA BEFORE AND AFTER DREDGING IN TWO WISCONSIN SPRING PONDS

| Taxa | Krause Springs | | | | Sunshine Springs | | | |
|---|---|---|---|---|---|---|---|---|
| | 1968–69 | | 1975 | | 1968–69 | | 1975 | |
| | Means (org./m$^2$) | % | Means (org./m$^2$) | % | Means (org./m$^2$) | % | Means (org./m$^2$) | % |
| Oligochaeta | 54 | 4.2 | 2,460 | 70.1 | 53 | 4 | 3,503 | 56 |
| Hirudinea | 2.9 | 0.4 | 0.05 | < 0.06 | 2.4 | 0.4 | 0.6 | 0.1 |
| Gastropoda | 1 | 0.1 | 0.6 | 0.2 | 5.2 | 0.8 | 2 | 0.3 |
| *Gammarus* | 46 | 6 | 14 | 5 | 6.2 | 3.2 | 68 | 10.2 |
| *Hyalella* | 91 | 38 | 0.1 | < 0.06 | 2 | < 0.06 | 0 | 0 |
| Chironomidae | 1,825 | 49.8 | 716 | 20.6 | 4,113 | 91.2 | 2,230 | 31.8 |
| **Total** | **4,557** | **100** | **6,826** | **100** | **4,972** | **100** | **14,758** | **100** |

After dredging, marl substrates predominated and areas of exposed mineral soils increased, providing approximately 1 additional meter of water depth in each pond. Water temperature and concentrations of dissolved materials did not change significantly. Dredging completely eliminated aquatic macrophytes and plant recolonization proceeded slowly. Recolonization first became evident about 1 year after dredging. In Sunshine Springs, biomass of *Chara* reached about 10 percent of pre-dredging levels after 5 years.

Densities of benthic organisms were severely reduced in the short-term by dredging, but recolonization was rapid. Oligochaetes recolonized rapidly and became the most numerous taxa and 4 to 5 years after dredging; they comprised 56 to 70 percent of all benthic organisms. Combined densities of all benthic taxa in Krause Springs was 50 percent higher than pre-dredging values and those in Sunshine Springs were nearly three times as great as pre-dredging densities, largely due to increased oligochaetes. Densities of the cladocerans *Daphnia* and *Bosmina* increased after dredging and the amphipod *Gammarus* reached pre-dredging levels within 5 years. The density of chironomids was reduced by 61 and 46 percent after dredging in Krause and Sunshine Springs, respectively. Leeches, *Hyalella*, and sialids were common in organic sediment, but decreased significantly following dredging. Zooplankton density was too low to allow detection before dredging and increased within 1.5 years, dominated by large populations of *Daphnia ambigua* and *Bosmina coregoni*.

Fish communities were temporarily altered by dredging. When benthic organisms, the primary food of trout, experienced decreased densities due to dredging, the growth rates of trout declined. As benthic communities recolonized, trout growth rates also increased. In shallow ponds, trout densities fluctuated greatly because of large-scale emigrations and immigrations. After dredging, emigrations were much reduced. The standing crop of brook trout in Krause Springs changed little after dredging, because numbers of trout hatched in the pond annually did not appreciably increase. Conversely, at Sunshine Springs, there was a marked increase in recruitment, and 5 years after dredging trout biomass was nearly triple that of pre-dredging levels. Brown trout (*Salmo trutta*), all of which were emigrants, accounted for more than half of the biomass increase.

Aquatic vegetation did not recover; however, the purpose of the dredging was to remove organic sediment and increase water depth to levels that would prevent the growth of invasive aquatic vegetation and development of filamentous algae mats. Accumulation of organic matter from allochthonous sources and native aquatic vegetation will likely enhance benthic productivity of the predominantly marl substrates.

### *RIVER HULL, ENGLAND (PEARSON, 1984)*

The effects of dredging were studied on the River Hull in England. The River Hull is a lowland stream with average discharges of up to 700 cubic feet per second (cfs) during flooding. Invertebrate populations were measured monthly at one station (Station 24) 17 months before dredging until 5 months after dredging, and at another station (Station 22) from 5 months before dredging to 17 months after dredging. Deposition of fine sediments increased during periods of low flow but was washed out during high winter flows. Several key metrics used to characterize the benthic community for the period before and after dredging at each of the dredged stations are shown in Table 7.

At Station 24, current velocity and the distribution of substratum were not greatly affected by dredging, despite substratum removal. Macrophytes were not present throughout the sampling period. The amphipod *Gammarus pulex* was the most abundant species, and oligochaetes were the next most abundant at Station 24 before and after dredging. In the 5 months following dredging in December 1972, the prevalence of the snail *Potamopyrgus jenkinsi* increased in frequency of occurrence and abundance. Mayflies were also more popular following dredging, and Shannon diversity, number of taxa, and biomass were similar to pre-dredging levels only several months following dredging. Total abundance in 1973 appeared to be similar to pre-dredge levels in the same months of 1972.

## TABLE 7 RIVER HULL SEDIMENT INVERTEBRATE METRICS BEFORE AND AFTER DREDGING

| | | Station 24 | | | | Station 22 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Abundance** | **Biomass** | **Number of Taxa** | **Shannon-Weaver Index** | **Abundance** | **Biomass** | **Number of Taxa** | **Shannon-Weaver Index** |
| ***1971*** | June | NS | | | | 495 | 3.4 | 18 | 3.4 |
| | July | 661 | 1.8 | 9 | 1.3 | 475 | 4 | 18 | 3.3 |
| | August | 765 | 2.3 | 10 | 0.8 | 760 | 6.9 | 19 | 3.8 |
| | September | 2,216 | 7.5 | 9 | 0.3 | 1,471 | 15.9 | 28 | 3.7 |
| | October | 1,502 | 3.6 | 7 | 0.3 | 1,662 | 17.5 | 23 | 3.6 |
| | November | 2,545 | 8.2 | 7 | 0.3 | 2,940 | 24.1 | 25 | 3.3 |
| | December | 2,010 | 8.1 | 6 | 1.2 | NS | | | |
| ***1972*** | January | 1,566 | 7 | 7 | 0.8 | **845** | **10.5** | **12** | **2.6** |
| | February | 751 | 6.5 | 14 | 1.8 | **677** | **10.1** | **17** | **3.1** |
| | March | 477 | 5.1 | 7 | 1.5 | **428** | **8.4** | **16** | **2.8** |
| | April | 489 | 5.1 | 8 | 1.7 | **207** | **5.9** | **16** | **3.4** |
| | May | 1,133 | 8.3 | 11 | 1.7 | **147** | **1.2** | **12** | **2.7** |
| | June | 4,345 | 8.2 | 16 | 1.8 | **234** | **2.2** | **17** | **2.3** |
| | July | 3,285 | 12.7 | 12 | 0.8 | **147** | **1** | **20** | **3.7** |
| | August | 2,633 | 6.9 | 22 | 2.3 | **575** | **4.2** | **25** | **3.2** |
| | September | 3,567 | 7.1 | 16 | 1.1 | **852** | **7.4** | **25** | **3.2** |
| | October | 1,309 | 4.7 | 14 | 1.2 | **705** | **6.8** | **22** | **2.9** |
| | November | 1,988 | 2.1 | 11 | 1.6 | **404** | **2.6** | **17** | **2.8** |
| | December | 1,436 | 2.6 | 8 | 1.4 | **314** | **3.2** | **15** | **2.3** |
| ***1973*** | January | **675** | **2.4** | **12** | **0.7** | **449** | **4.3** | **20** | **3.1** |
| | February | **549** | **1.8** | **10** | **0.8** | **463** | **3** | **22** | **3.4** |
| | March | **762** | **2.3** | **14** | **0.9** | **519** | **5.9** | **19** | **3.3** |
| | April | **842** | **6.7** | **7** | **0.6** | **298** | **6.8** | **20** | **3.5** |
| | May | **923** | **9.5** | **13** | **0.9** | **275** | **3.6** | **20** | **3** |

**Notes:**
**Bold** – Indices Following Dredging
NS – Not Sampled

Dredging at Station 22 caused marked drops in current velocity following the removal of substratum and most of the plants. The new substrate consisted of soft silt and plant fragments overlying a clay/gravel bed. The aquatic macrophyte *Elodea canadensis* and green algae *Cladophora* spp. became dominant following dredging at Station 22. Before dredging, oligochaetes, leeches, gastropods, and chironomids were dominant. Chironomids were present in similar densities before and after dredging, but densities of oligochaetes and some gastropods declined quickly following dredging. The caddisfly *Hydroporus* spp., which was one of the more populous organisms before dredging became the dominant organism afterwards. The number of taxa and Shannon diversity showed a fairly quick recovery following dredging.

At both stations, the number of taxa of benthic invertebrates had recovered in 6 months but abundance and community composition had not returned to pre-disturbance conditions after 1 year. Fauna of the faster flowing, more lotic segment (Station 24) appeared to be better able to withstand mechanical disturbance (current and turbulence) and to repopulate than fauna of the more lentic segment (Station 22).

### *BRYANT MILL POND DREDGING PROJECT – WISCONSIN (EPA Region 6 Communication)*

Allied Paper, Inc. widened a stream channel flowing from Bryant Mill Pond by dredging and regrading the areas adjacent to the stream channel. Remediation was completed in March 1999 without any habitat enhancement. Figures 3 and 4 are pictures just following remediation, and Figures 5 and 6 are pictures 4 months following remediation of each of the locations shown on Figures 3 and 4, respectively. Wetland and aquatic vegetation has obviously established following remediation in areas disturbed by dredging or regrading.

**Figure 3 Lower Stream Reach Following Remediation, March 1999**

**Figure 4 Upper Stream Reach Following Remediation, March 1999**

**Figure 5 Lower Stream Reach Following Remediation, August 1999**

**Figure 6 Upper Stream Reach Following Remediation, August 1999**

***COLLINGWOOD HARBOUR – ONTARIO, CANADA (ENVIRONMENT CANADA, 1998)***

Sediment in Collingwood Harbour was contaminated with metals from historical shipbuilding activities. Dredging was performed as part of navigation maintenance in the harbor in 1986, a pilot remedial dredging project in 1992, and as the cleanup remedy in 1993 that resulted on the removal of 2.45 acres. Sediments consisted of soft silt overlying clay and bedrock.

Benthic invertebrate identification was conducted in 1992 and 1993 throughout the harbor to determine baseline conditions. Oligochaetes were found to be abundant in areas of low-level toxicity as shown in the analysis of the benthic community structure. Following dredging, benthic community structure and biomass resembled control sites of comparable physical and chemical characteristics.

## 3.3 ENVIRONMENTAL EFFECTS OF CAPPING ON BIOTA, FISH, AND SAV

There are no capping projects with demonstrated long-term monitoring or effectiveness that exist in any riverine system anywhere in the world. Thus, evaluating the short- and long-term environmental effects of capping can only be estimated from projects done in marine or lake environments. The FS listed a number of capping projects that have been conducted around the world. Despite the fact that a number of caps have been built, only two projects collected specific post-placement environmental effects information. These are discussed below.

### *SIMPSON CAPPING PROJECT – TACOMA, WASHINGTON (STIVERS AND SULLIVAN, 1994)*

The St. Paul Waterway Area Remedial Action and Habitat Restoration Project was one of the first aquatic Superfund remediations in the country. The previously contaminated site was capped and intertidal habitat was designed for the cap surface to encourage recolonization by benthic infauna and macrophytes (algae), and use by fish and birds. Physical and biological monitoring was performed for 5 years following cap placement.

A sand cap with a thickness of 2.5 to 6.5 meters was placed over the 17-acre area in 1987 and 1988. Benthic invertebrate abundance and complexity monitored annually from 1988 to 1993 have shown an overall increase. Immediately after construction, the area was essentially new, uncolonized habitat. The total abundance of benthic organisms increased steadily through 1992. In 1993, there was a slight decrease in the total abundance measured at the site; however, the overall trend has been one of increasing benthic abundance from essentially zero in 1988 to a range of 1,172 to 9,718 organisms per station in 1993. Following remediation, benthic invertebrate community abundance and diversity observed at the project site have been comparable to those found at various reference sites tested, indicating that the community resembles a typical healthy back-bay mudflat in Puget Sound.

Epibenthic populations and variability since cap construction has been similar to the ranges and variability found at various reference sites tested during the 5 years of monitoring. Macrophyte coverage at the site has increased greatly since construction, appearing to achieve the maximum possible coverage given the availability of hard surfaces for macrophyte attachment at the site.

### *SODA LAKE, WYOMING (THERMORETEC, 2001)*

A demonstration cap was placed over refinery residuals in a settling pond located near Casper, Wyoming. A pilot capping project was conducted, placing 3 feet of clean sand over the highly plastic process residuals. Benthic invertebrates were collected prior to cap placement from ten stations in March 2000 and 11 months following cap placement (June 2001) from the same ten stations, four of which were located on the cap.

Benthic infauna appeared to be relatively tolerant of the organic pollution present in the Inlet Basin sediment. Chironomids accounted for approximately 42 percent of the total benthic invertebrate population in the organic sediments. The remainder was composed mostly of gastropods and *Hyalella azteca*. Oligochaetes were also identified prior to capping but in fewer numbers than chironomids, gastropods, and *Hyalella*. Twenty-eight different organisms were identified in Inlet Basin sediment, with the total taxa per station averaging nine. The number of taxa ranged from fourteen (two stations) to three (two stations). Shannon-Weaver diversity (H') was estimated for each station and for the group average; higher indices indicate greater diversity. The average diversity (H') was 2.15 for the Inlet Basin; diversity indices ranged from 1.10 to 2.94.

Following capping, chironomids and oligochaetes accounted for approximately 32 and 58 percent of the total benthic population, respectively. Table 8 contains results of cap stations and non-cap stations 11 months following cap placement. Chironomids were approximately twice as abundant and oligochaetes were greater than six times as abundant at cap stations than off-cap stations 11 months following cap placement. Shannon diversity was lower at both cap and off-cap stations than the baseline investigation, averaging 0.32 and 0.17, respectively. Prior to cap placement, oligochaetes were present at only five of the ten stations sampled, but dominated following cap placement.

Seasonal differences in benthic population are likely present; however, comparisons of cap stations to off-cap stations may be made. The substrate change from silt and clay to sand and the absence of organic content are likely the cause of the decline in diversity.

### 3.3.1 Other Disturbances

#### *CHANNELIZATION*

Channelization greatly degrades and simplifies in-stream habitat by eliminating channel river meanders and riparian vegetation and removing snags and in-stream and streamside vegetation. Long, uninterrupted stretches of uniform habitat are developed by unifying stream gradient and removing complexities in rivers, likely reducing the abundance and species richness of the colonizing invertebrate communities (Hortle and Lake, 1982).

Effective habitat mitigation strategies have decreased siltation and increased pool volume, allowing recovery to occur within 5 years (Hunt, 1976; Edwards et al., 1984). In general, recovery in channelized systems has been mediated by organism-specific food requirements and habitat preferences. In the Olentangy River, Ohio, productive backwater refugia ensures the continued presence of bottom-dwelling detritus feeders (carp) and species such a channel catfish (Arner et al., 1976; Edwards et al., 1984). In the Luxapalila River in Mississippi, fish populations are still not considered recovered after 52 years (Arner et al., 1976).

Many channelization projects eliminate nearby source areas for recolonization, causing recovery and recolonization to be long-term. Milner (1987) determined that in 25-year-old glacial stream invertebrate communities still have not achieved maximum diversities despite achieving maximum densities 14 years earlier. This study illustrates that colonization (and hence recovery) is a long-term process when there are no upstream source areas for drift and refugia areas are distant.

#### *FLOODS*

Floods are rarely of sufficient magnitude to remove the entire stream biota (Minshall et al., 1983). Nevertheless, floods disturb community structure and function, sometimes forcing recovery times to be long, especially when floods are uncommon in the area. Frequent floods disrupt the established algal community, often favoring well-resistant taxa (Milner, 1994). In a small Irish river, a flood reduced macroinvertebrate densities to less than 5 percent of pre-flood levels (Giller et al., 1991). Recovery was less than 50 percent of the original density after 2 years; however, there was no apparent effect on the resident salmonid populations.

## TABLE 8 BENTHIC INVERTEBRATE COUNTS 11 MONTHS FOLLOWING CAP PLACEMENT ON THE INLET BASIN – SODA LAKE

| Taxa | SLIB-01 | SLIB-02 | SLIB-03 | SLIB-04 | Cap Average | SLIB-5 | SLIB-06 | SLIB-07 | SLIB-8 | SLIB-9 | SLIB-10 | Non-cap Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Insecta*** | | | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | | | |
| *Caenis* sp. | 1 | 0 | 3 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 | 1 |
| Trichoptera | | | | | | | | | | | | |
| *Lepidostoma* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Odonata | | | | | | | | | | | | |
| *Coenagrionidae* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Diptera | | | | | | | | | | | | |
| *Chironomidae* | 63 | 17 | 108 | 1 | 47 | 3 | 82 | 1 | 39 | 20 | 1 | 24 |
| ***Annelida*** | | | | | | | | | | | | |
| Oligochaeta | | | | | | | | | | | | |
| *Unid. Oligochaeta* | 154 | 32 | 139 | 7 | 83 | 1 | 1 | 0 | 65 | 4 | 1 | 12 |
| ***Nematoda*** | | | | | | | | | | | | |
| *Unid. Nematoda* | 29 | 4 | 4 | 0 | 10 | 0 | 0 | 0 | 2 | 1 | 0 | 1 |
| ***Crustacea*** | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | | |
| *Hyalella* sp. | 1 | 0 | 3 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 0 | 1 |
| ***Mollusca*** | | | | | | | | | | | | |
| Gastropoda | 0 | 0 | 4 | 0 | 1 | 0 | 4 | 0 | 7 | 1 | 0 | 2 |
| *Fossaria* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Lymnaeidae* | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Physella* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Physidae* | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 1 |
| *Planorbidae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Neotaenioglossa | | | | | | | | | | | | |
| *Hydrobiidae* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Total (organisms/m$^2$)*** | **11,101** | **2,391** | **11,618** | **369** | **6,370** | **207** | **4,310** | **44** | **5,078** | **1,137** | **74** | **1,808** |
| Number of Taxa | 7 | 3 | 7 | 2 | 6 | 2 | 7 | 1 | 7 | 4 | 2 | 6 |
| Shannon-Weaver H' | 0.22 | 0.15 | 0.20 | 0.00 | 0.14 | 0.00 | 0.45 | 0.00 | 0.32 | 0.50 | 0.00 | 0.21 |
| Evenness | 0.26 | 0.32 | 0.24 | 0.00 | 0.20 | 0.00 | 0.53 | 0.00 | 0.38 | 0.83 | 0.00 | 0.29 |

Other studies indicate that fish are usually able to quickly recover from catastrophic flooding. Rainbow trout recolonized a 1-mile stretch of a California river within 4 years following the complete elimination of the resident population (Lambert, 1988). Matthews (1986) reported fish communities to have recovered in 8 months following a catastrophic flood in an Arkansas stream.

### *NEW STREAM CHANNELS*

Newly constructed stream channels and relocated stream channels often are completely without any invertebrate or algal populations. The time to recovery is fairly quick if nearby colonization sources are available. The number of taxa colonizing reached an equilibrium after approximately 100 days in a new, constructed Canadian stream channel (Williams and Hynes, 1976) and a restored stream channel damaged by coal surface mining (Gore, 1979). Although reduced recruitment of new species was observed after approximately 200 days following construction of a new stream in Sweden, chironomids were found first in newly emergent glacial streams (Malmqvist et al., 1991), which was similar to colonization of glacial streams of different age (Milner, 1987).

# 4 POTENTIAL IMPACTS OF REMEDIAL ACTIONS

This section discusses the potential for adverse effects and recovery following either of the two potential remedies (dredging or capping) proposed for the Lower Fox River. It addresses the issue that removal or burial of sediment adversely and permanently affects the benthic invertebrates and fish population currently inhabiting the River. Additionally, the occurrence of SAV is assessed to better determine the actual impact of the proposed dredging footprint to 1 ppm total PCBs.

## 4.1 POTENTIAL FOR RECOVERY FOLLOWING REMEDIAL ACTION

This section estimates the effect of dredging or capping on each habitat and how these changes may affect the food web of the Lower Fox River.

### 4.1.1 Habitat

Important habitats crucial to maintaining the fish population in the Lower Fox River are fast-flowing areas with hard substrate, including sand, gravel, and cobble habitat, and shallower, slower flowing areas that have soft sediment and provide shelter in the form of submerged and emergent aquatic vegetation. These habitats are further discussed to better understand the effects on fish from dredging. The majority of the substrate targeted for dredging is composed of soft sediments. Fish migrating away from dredging activities will need to find suitable habitat where they may successfully feed and spawn.

#### *HARD SUBSTRATE*

Areas targeted for dredging or capping in the Lower Fox River are predominantly soft, aqueous, and silty sediments. Many fishes in the Lower Fox River utilize open substrate like rock with high dissolved oxygen for spawning and adult habitat. These areas are not targeted for dredging. Fish utilizing rock substrate with fast-flowing water include common and emerald shiners, walleye, and rainbow smelt. The presence of riprap on riverbanks provides additional spawning habitat in each OU for walleye and other fish that require rocky substrate for spawning. Much of the fast flowing, rocky substrate in the Lower Fox River is located in OU 2. This area and riffles created by dams in OUs 3 and 4 (none of which are targeted for dredging) will remain unimpacted and be important for fish requiring this type of habitat.

Historical walleye spawning enhancement projects and walleye stocking programs have been successfully undertaken in the Lower Fox River by the Wisconsin Department of Natural Resources and City of De Pere, Wisconsin. New spawning habitat was created at two locations in the Lower Fox River and spawning habitat was enhanced at another location by increasing desirable substrate adjacent to a good quality, highly used spawning area (Lychwick, 1995). Substantial increases in fingerling walleye and egg survival appear to have occurred with the best success at Voyageur Park, where egg deposition was estimated at 5.2 million eggs (Lychwick, 1995). Although these areas are to be left undisturbed as part of the Proposed Plan, they do demonstrate the potential success of similar management programs following disturbance, if necessary.

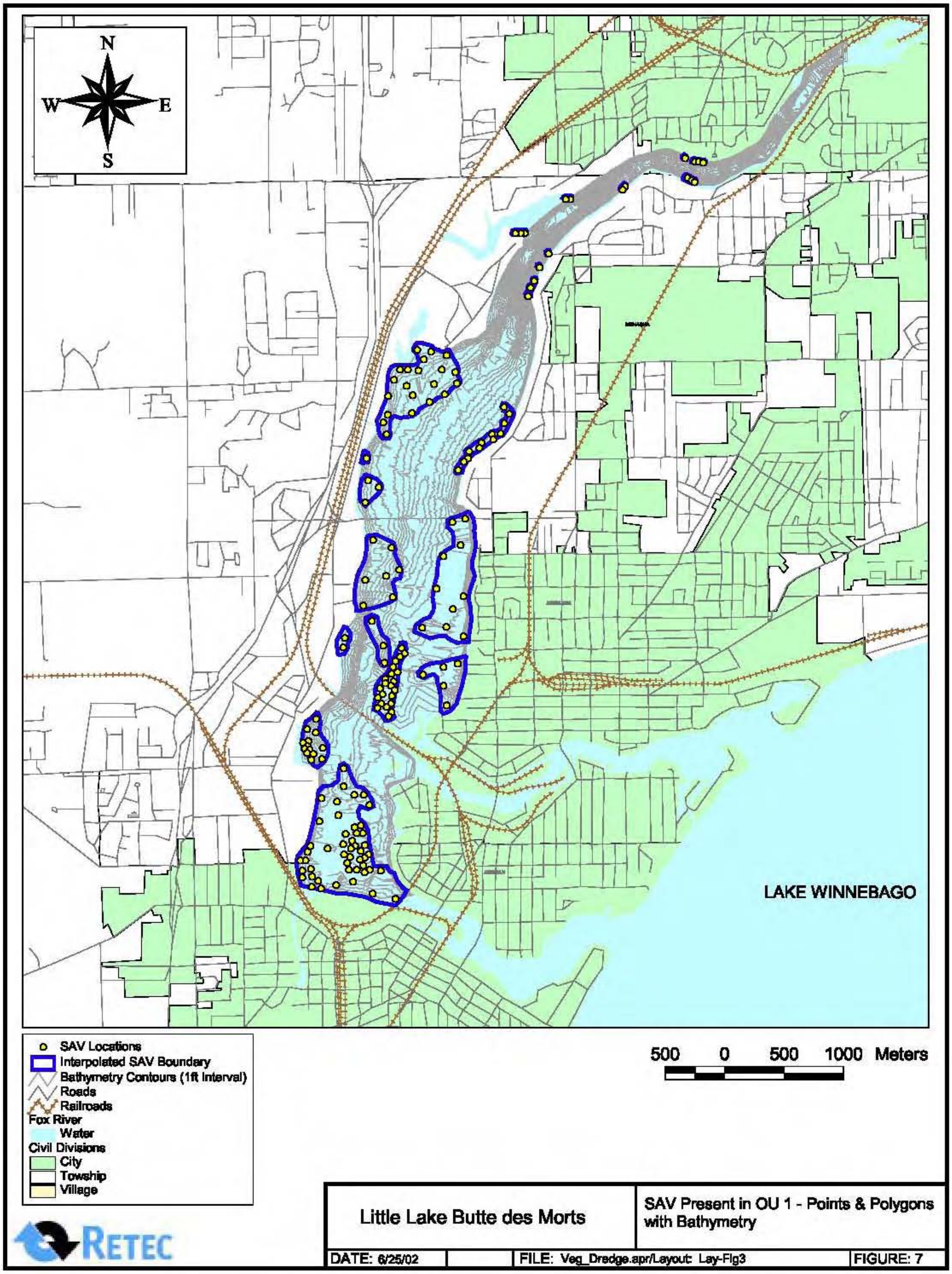
### *SAV*

SAV and emergent aquatic vegetation are likely to grow in the soft, aqueous, and silty sediments, some of which is proposed for dredging or capping. SAV is an important habitat that supports many of the resident fish species in the Lower Fox River. Macrophytes provide shelter and oviposition sites for benthic invertebrates, and substrata for epiphytic algae and invertebrates (Harrod, 1964; Westlake, 1975; Cattaneo and Kalff, 1980). Vegetation provides food in the form of epiphytic algae, decaying plant material, and fine particulate organic matter that accumulates in plant beds (Kaenel et al., 1998). Juvenile fish are also able to utilize the vegetated areas as nursery habitat because of slower flows and shelter from predators (Aldridge, 2000). Golden shiners, carp, and yellow perch require aquatic vegetation at some point for spawning or adult habitat. Other juvenile fish use the vegetated areas as shelter and protection from predators.

The fish present in the Lower Fox River are mobile species that seek out appropriate spawning habitat. Many naturally occurring backwater areas are present in Little Lake Butte des Morts as well as other artificial backwater areas resulting from dams in the Lower Fox River. These areas, along with tributaries entering along the entire River, are valuable backwater habitat that provide sources from which migration may occur and shelter during disturbances like dredging. Submerged and emergent aquatic vegetation is key for providing shelter in these areas. Studies have shown the benefit of natural refugia in the form of off-channel brood ponds as an important factor in speeding recovery of disturbed rivers and streams (Detenbeck et al., 1992).

SAV is most prevalent in Little Lake Butte des Morts (OU 1), and present in backwater areas in OUs 3 and 4. Little Lake Butte des Morts contains slower velocities, shallower water depths, and more fluctuating water levels than OUs 3 and 4. Figure 7 shows SAV distribution in Little Lake Butte des Morts in relation to 1-foot bathymetric contour intervals. Also contained on this figure are polygons created by Exponent to group each of the SAV locations identified in the survey.

Exponent (1999) estimated that 60 percent of the shoreline of OU 1 contains SAV. Blasland, Bouck and Lee (BBL) cited the investigation conducted by Exponent (1999) to state that 48 percent of OU 1 is covered with SAV. However, it is likely that many of their estimates are inflated because of the inaccurate assumption that blooms of filamentous green algae that are "associated with SAV" actually indicate the presence of SAV. Filamentous green algae is widespread in Little Lake Butte des Morts, often drifting from Lake Winnebago during southerly winds in sizable portions. Several of the photos provided by Exponent and described as SAV indeed are nothing more than filamentous green algal blooms.


N
W
E
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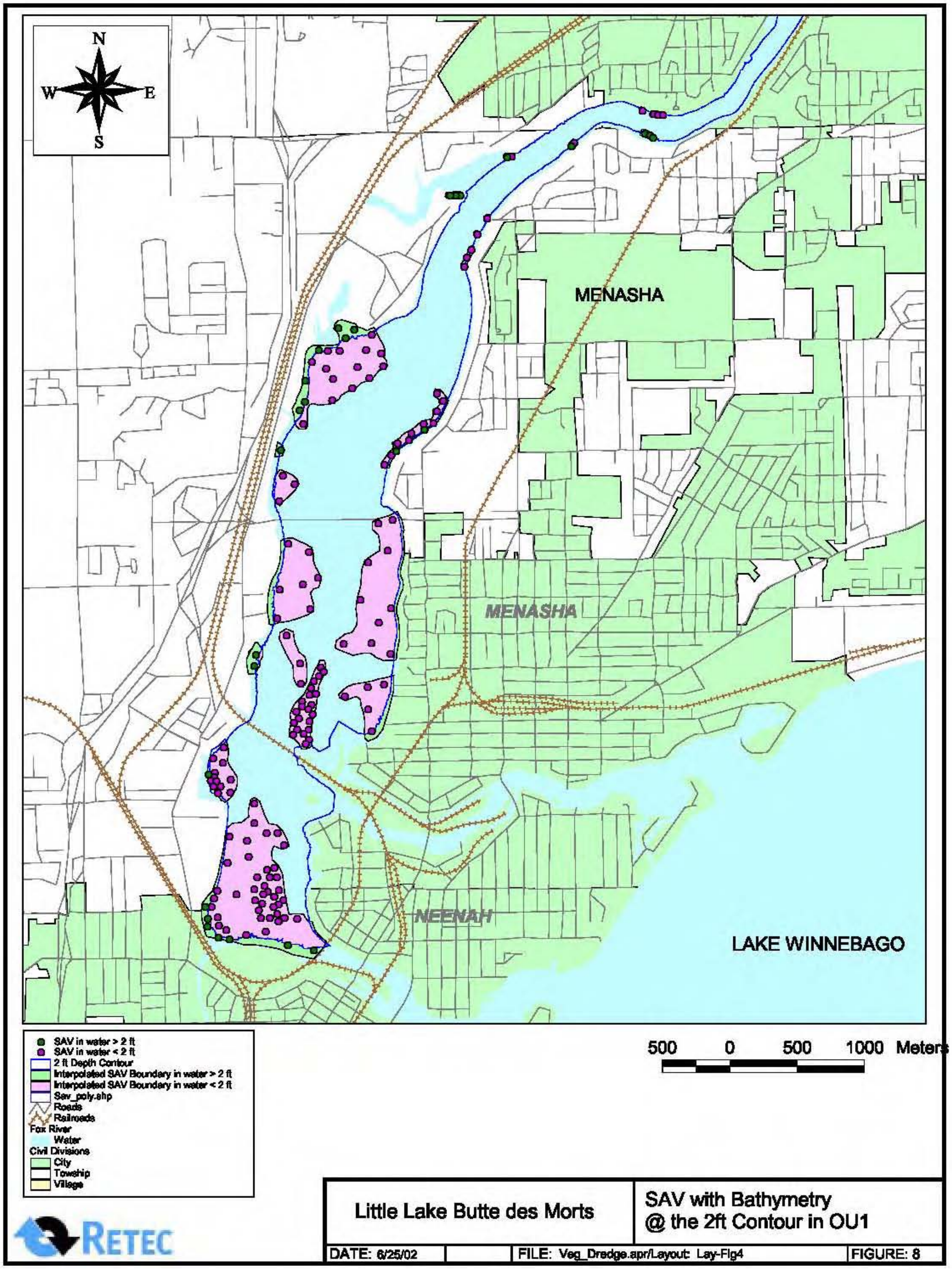
LAKE WINNEBAGO
SAV Locations
Interpolated SAV Boundary
Bathymetry Contours (1ft Interval)
Roads
Railroads
Fox River
Water
Civil Divisions
City
Towship
Village
500 0 500 1000 Meters
RETEC
Little Lake Butte des Morts
SAV Present in OU 1 - Points & Polygons with Bathymetry
DATE: 6/25/02
FILE: Veg_Dredge.apr/Layout: Lay-Fig3
FIGURE: 7

Additionally, the suspended sediments of Little Lake Butte des Morts reduces light penetration to such a degree that many species of SAV are unlikely to establish in water deeper than about 2 feet. Turbidity, a measure of suspended particles in water, has been recorded at greater than 100 mg/L before the beginning of the pilot dredging projects (RETEC, 2002b), limiting the depth to which aquatic vegetation could develop.

Figure 8 shows the distribution of SAV above and below the 2-foot bathymetric contour for Little Lake Butte des Morts. As shown on the figure, SAV is present in areas shallower than approximately 2 feet, but was also judged to be present in water deeper than 2 feet in many parts of Little Lake Butte des Morts. Because SAV presence is identified by observations made at single locations, it is unacceptable to infer that SAV is present consistently between each point. Polygons that group SAV locations are shown on Figure 7.

Calculations were performed using a Geographic Information System (GIS) to estimate the total area of SAV in Little Lake Butte des Morts using these polygons. These results are contained in Table 9. Approximately 29.9 percent, or 1,726,800 square meters ($m^2$), of Little Lake Butte des Morts is covered by SAV as surveyed by Exponent (1999). It is likely this is an overestimate of the coverage of SAV due to Exponent's assumptions regarding the presence of filamentous green algae as indicating SAV presence.


N
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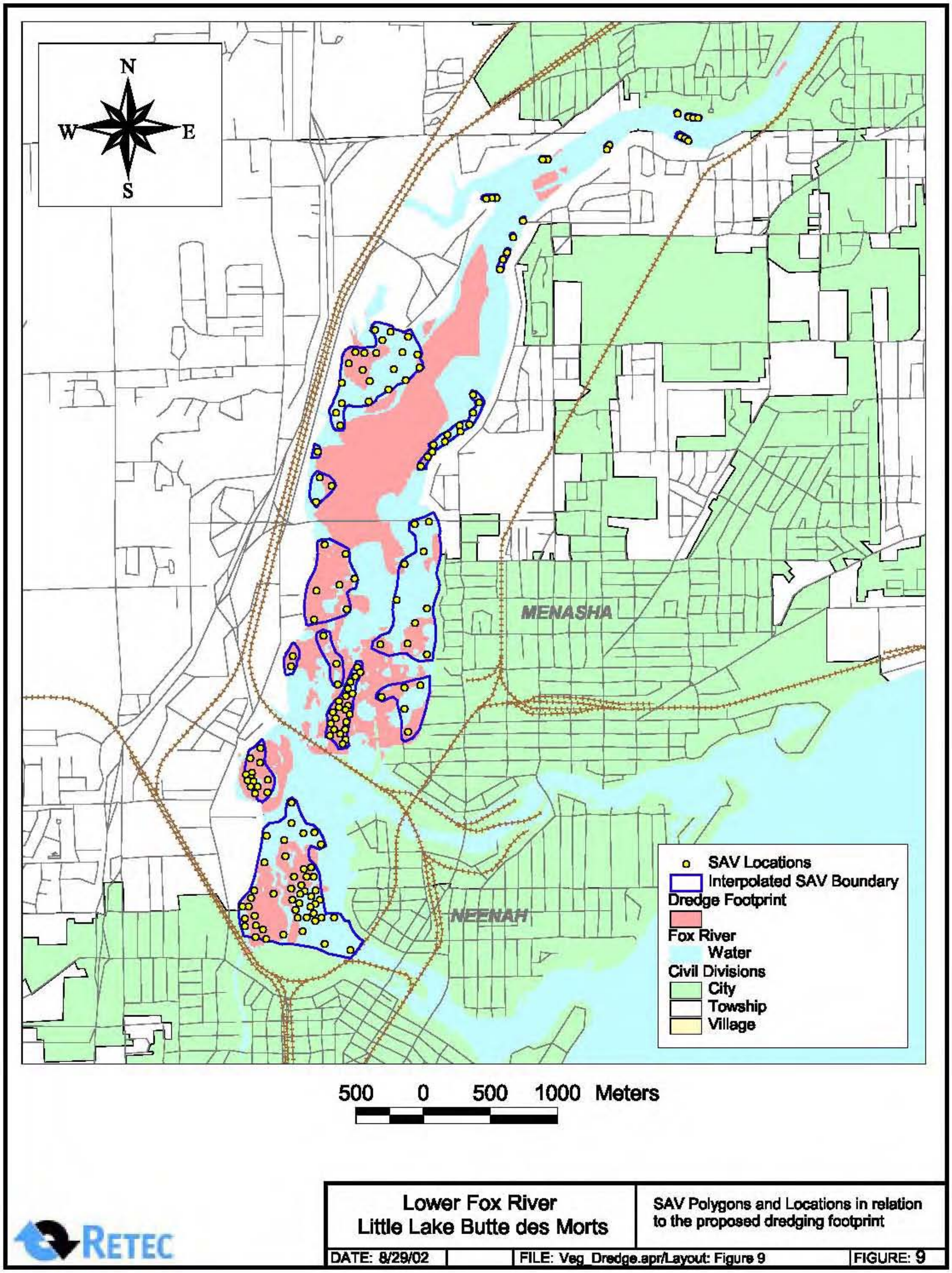
MENASHA
NEENAH
LAKE WINNEBAGO
SAV in water > 2 ft
SAV in water < 2 ft
2 ft Depth Contour
Interpolated SAV Boundary in water > 2 ft
Interpolated SAV Boundary in water < 2 ft
Sav_poly.shp
Roads
Railroads
Fox River
Water
Civil Divisions
City
Towship
Village
500 0 500 1000 Meters
RETEC
Little Lake Butte des Morts
SAV with Bathymetry @ the 2ft Contour in OU1
DATE: 6/25/02
FILE: Veg_Dredge.apr/Layout: Lay-Fig4
FIGURE: 8

## TABLE 9 AREA OF SUBMERGED AQUATIC VEGETATION AND DREDGING

| | Total Area ($m^2$) | Percent Coverage |
|---|---|---|
| ***Submerged Aquatic Vegetation*** | | |
| **Little Lake Butte des Morts** | | |
| Total Area of Little Lake Butte des Morts | 5,772,171 | — |
| Total Area of SAV in Little Lake Butte des Morts | 1,726,800 | 29.9% |
| Total area of SAV in < 2 feet water depth | 238,900 | 4.1% |
| *Calculation by Interpolated Polygons* | | |
| Total area of SAV inside dredge footprint | 734,400 | 42.5% |
| Total area of SAV outside dredge footprint | 992,400 | 57.5% |
| *Interpolation by Vegetation Presence/Absence* | | |
| Total SAV Points in Little Lake Butte des Morts | 376 | — |
| Total SAV points inside dredge footprint | 109 | 29.0% |
| Total SAV points outside dredge footprint | 267 | 71.0% |
| ***Dredging*** | | |
| **Estimated Dredged Footprint** | | |
| OU 1 | 2,130,900 | — |
| OU 2 | 995,300 | — |
| OU 3 | 4,071,100 | — |
| **Estimated Area Where Firm Subsurface Sediment Will Become Exposed** | | |
| OU 1 | 390,000 | 18.3% |
| OU 3 | 139,300 | 14.0% |
| OU 4 | 1,283,700 | 31.5% |

Estimates were also made to determine the portion of SAV anticipated to be dredged at the 1 ppm total PCB contour. Figure 9 shows the SAV polygons and locations in relation to the dredging footprint (RETEC, 2002b). As shown in Table 9, approximately 42.5 percent of the SAV present in Little Lake Butte des Morts will be dredged. Because the estimates of SAV predicted to be dredged are likely high, an additional analysis of the total number of locations where SAV was identified inside and outside of the dredge footprint was performed. As shown in Table 9, approximately 29 percent of the SAV locations identified during the Exponent survey are located inside the planned dredge footprint. The remainder will remain intact and undredged.

This is a substantial portion of SAV to remain unaffected by dredging. Much of the SAV currently present in Little Lake Butte des Morts is located in nearshore areas that are not targeted for dredging. SAV present in OUs 3 and 4 is estimated to be less than 2 and 3 percent shoreline coverage, respectively (Exponent, 1999). Figures 10 and 11 show SAV locations in relation to the proposed dredging footprints in OUs 3 and 4, respectively. Less than 1 percent of the dredge footprint of both OUs 3 and 4 will affect SAV.


N
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MENASHA
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SAV Locations
Interpolated SAV Boundary
Dredge Footprint
Fox River
Water
Civil Divisions
City
Towship
Village
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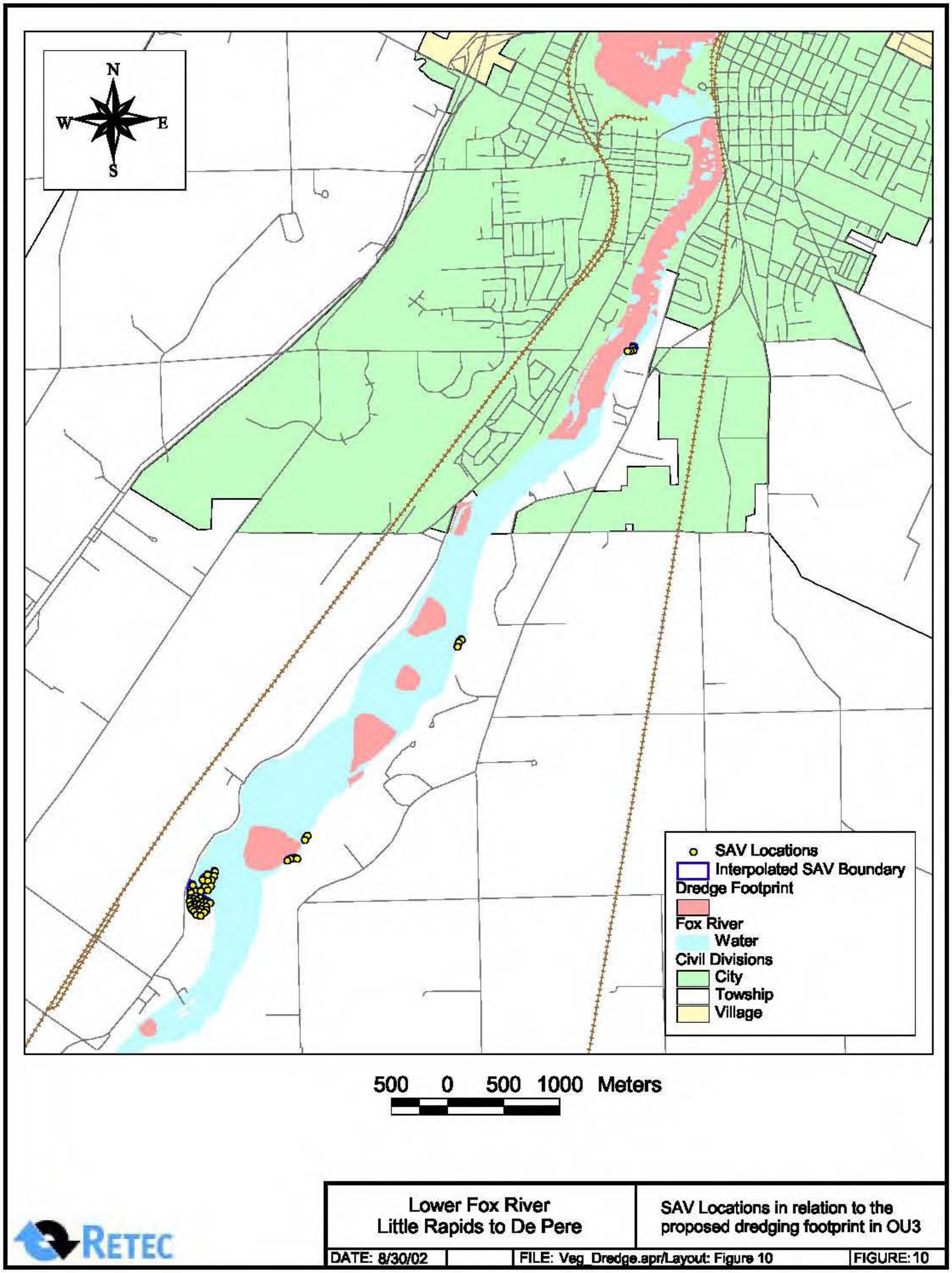
RETEC
Lower Fox River
Little Lake Butte des Morts
SAV Polygons and Locations in relation to the proposed dredging footprint
DATE: 8/29/02
FILE: Veg_Dredge.apr/Layout: Figure 9
FIGURE: 9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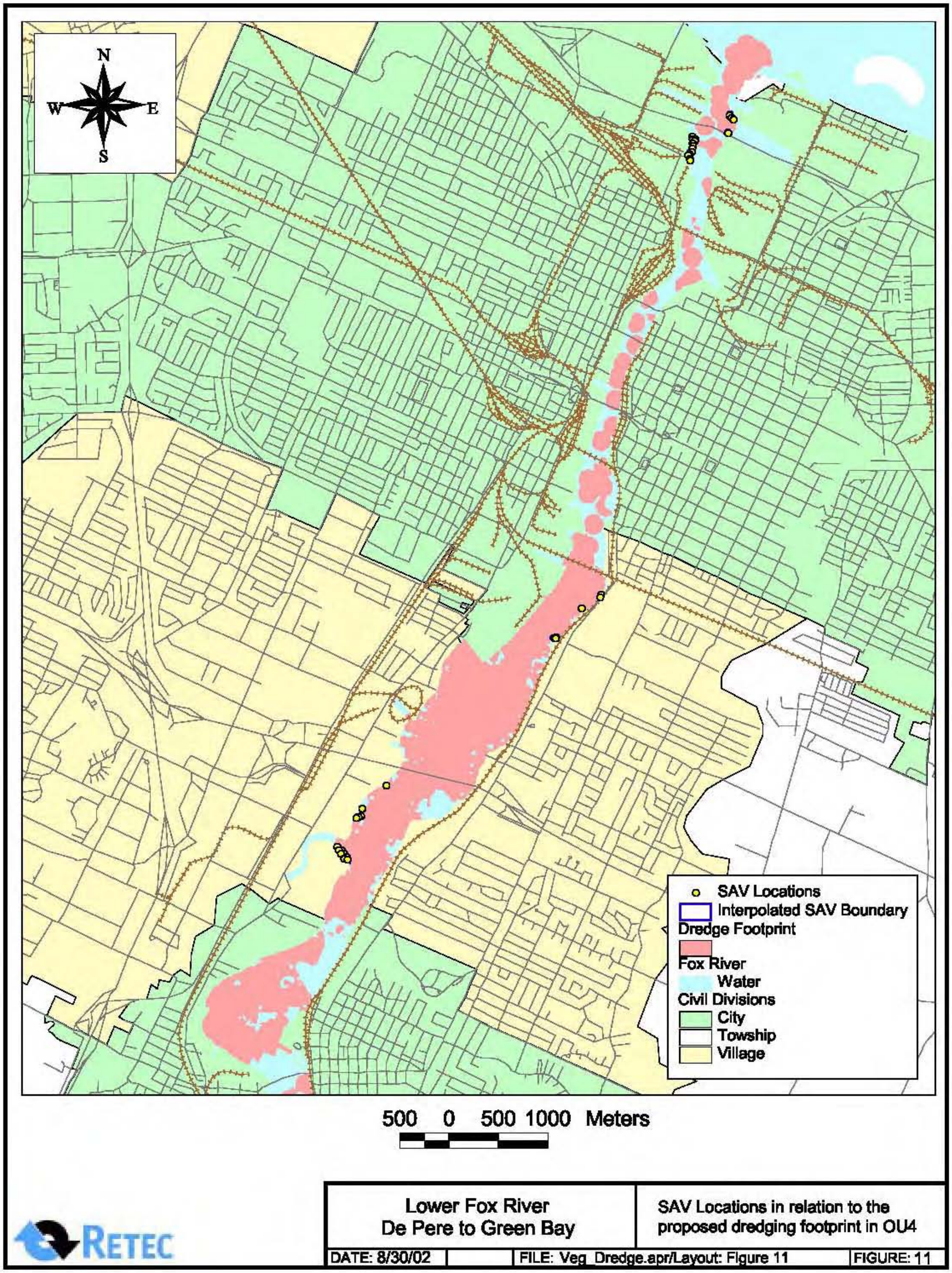
SAV Locations
Interpolated SAV Boundary
Dredge Footprint
Fox River
Water
Civil Divisions
City
Towship
Village
500 0 500 1000 Meters
RETEC
Lower Fox River
Little Rapids to De Pere
SAV Locations in relation to the proposed dredging footprint in OU3
DATE: 8/30/02
FILE: Veg_Dredge.apr/Layout: Figure 10
FIGURE: 10


N
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SAV Locations
Interpolated SAV Boundary
Dredge Footprint
Fox River
Water
Civil Divisions
City
Towship
Village
500 0 500 1000 Meters
RETEC
Lower Fox River
De Pere to Green Bay
SAV Locations in relation to the proposed dredging footprint in OU4
DATE: 8/30/02
FILE: Veg_Dredge.apr/Layout: Figure 11
FIGURE: 11

Although some vegetation will be dredged in Little Lake Butte des Morts, it is not anticipated that flow patterns will change. Slower flows, along with sources for reestablishment provided by nearby, undredged aquatic macrophyte beds support the potential for growth of additional submerged aquatic macrophytes. Waters flowing from Lake Winnebago supply consistent sources for seeds and nutrients that settle and stick in the organic sediment. Slower flow velocities through Little Lake Butte des Morts also provide substantial opportunity for seeds to settle into dredged and undredged sediments. Additionally, these macrophytes die back each winter. They reestablish in the spring either from rhizomes and existing root systems or by way of new seeds buried in the sediment.

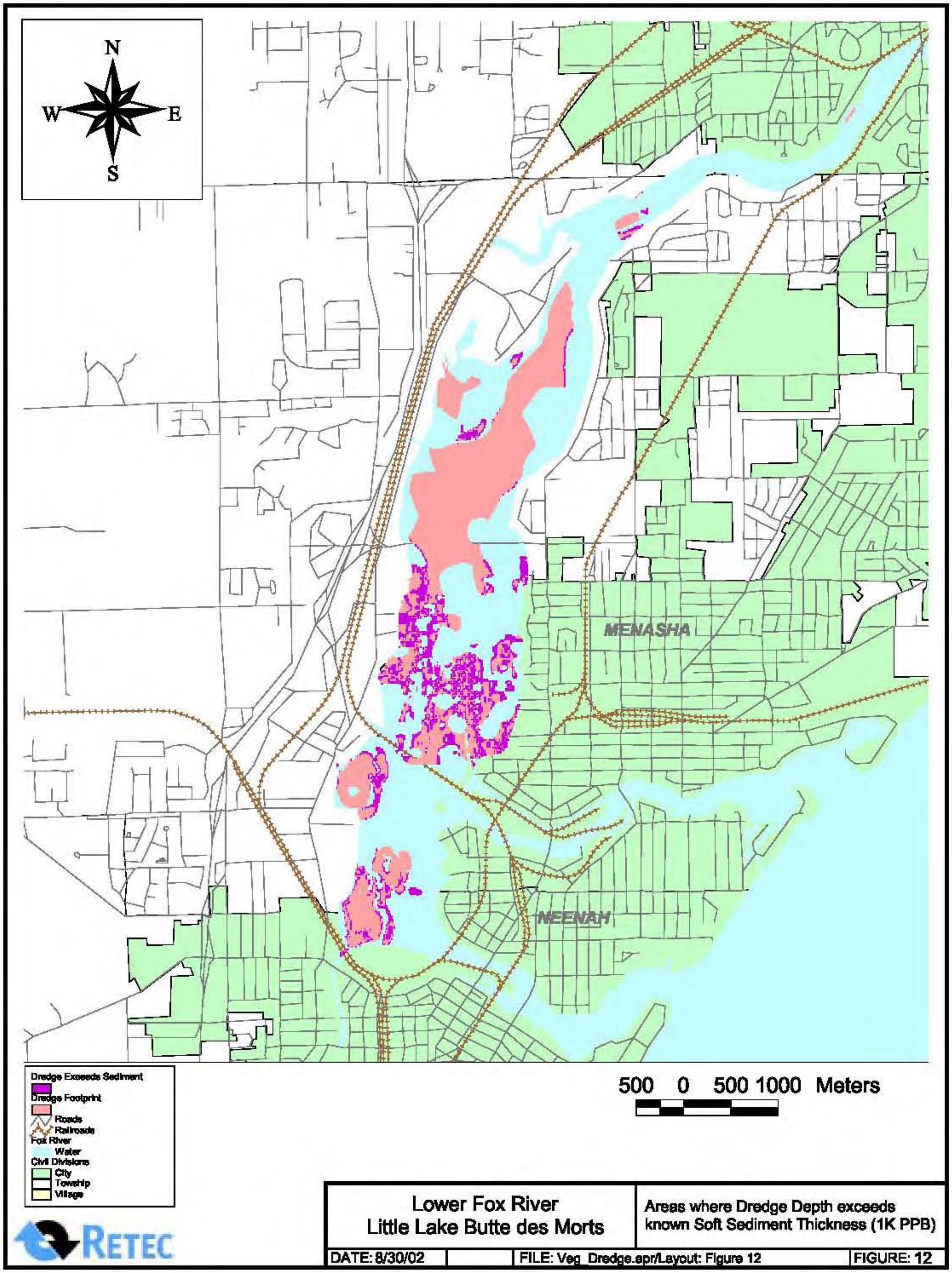
Dredging will increase water depth in some places, potentially preventing aquatic macrophytes from rooting where they were formerly present due to severe light attenuation, but more submerged habitat will be created in the shallower areas to counteract any losses in potential vegetation habitat due to deepening. However, dredged excavations tend to be filled with sediment during high flows (Harvey and Lisle, 1998), which will potentially reclaim former submerged vegetation habitat lost due to dredging.

Backwater areas that are associated with tributaries in OUs 3 and 4 will continue to provide suitable habitat for submerged and emergent aquatic vegetation. The presence of dams and locks will sufficiently maintain slower flows necessary for aquatic vegetation establishment. It is likely that aquatic vegetation located in backwater areas and slower flowing environments should reestablish, especially with the upstream seed sources of Little Lake Butte des Morts and Lake Winnebago.

#### *SOFT SUBSTRATE*

Dredging sediment in the Lower Fox River has the potential to cause a change in substrate. Different substrates present following dredging could influence the rate and type of recovery of the benthic and aquatic community. In an effort to better identify areas potentially at risk of substrate change, an investigation using a GIS was performed to determine the degree and location of substantive change following dredging. Anticipated dredge depth was summarized in the FS, and sediment thickness was interpolated using a GIS, based on poling data conducted as part of previous sampling activities (RETEC, 2002b). It is assumed that if dredging depth does not exceed sediment thickness, a change in substrate to the stiff, silty clay that is similar to the glacial till in the region will not occur.

Figures 12, 13, and 14 indicate the areas where proposed dredge depth exceeds sediment thickness for OUs 1, 3, and 4. Table 9 shows that approximately 18.3, 14.0, and 31.5 percent of the total dredged area for OUs 1, 3, and 4, respectively, will likely result in substrate changes. Regardless of interpolated dredge depths, dredging into the stiff sediment underlying the soft, upper layers will not occur. Substrate will only change in areas where all soft sediment is targeted for removal.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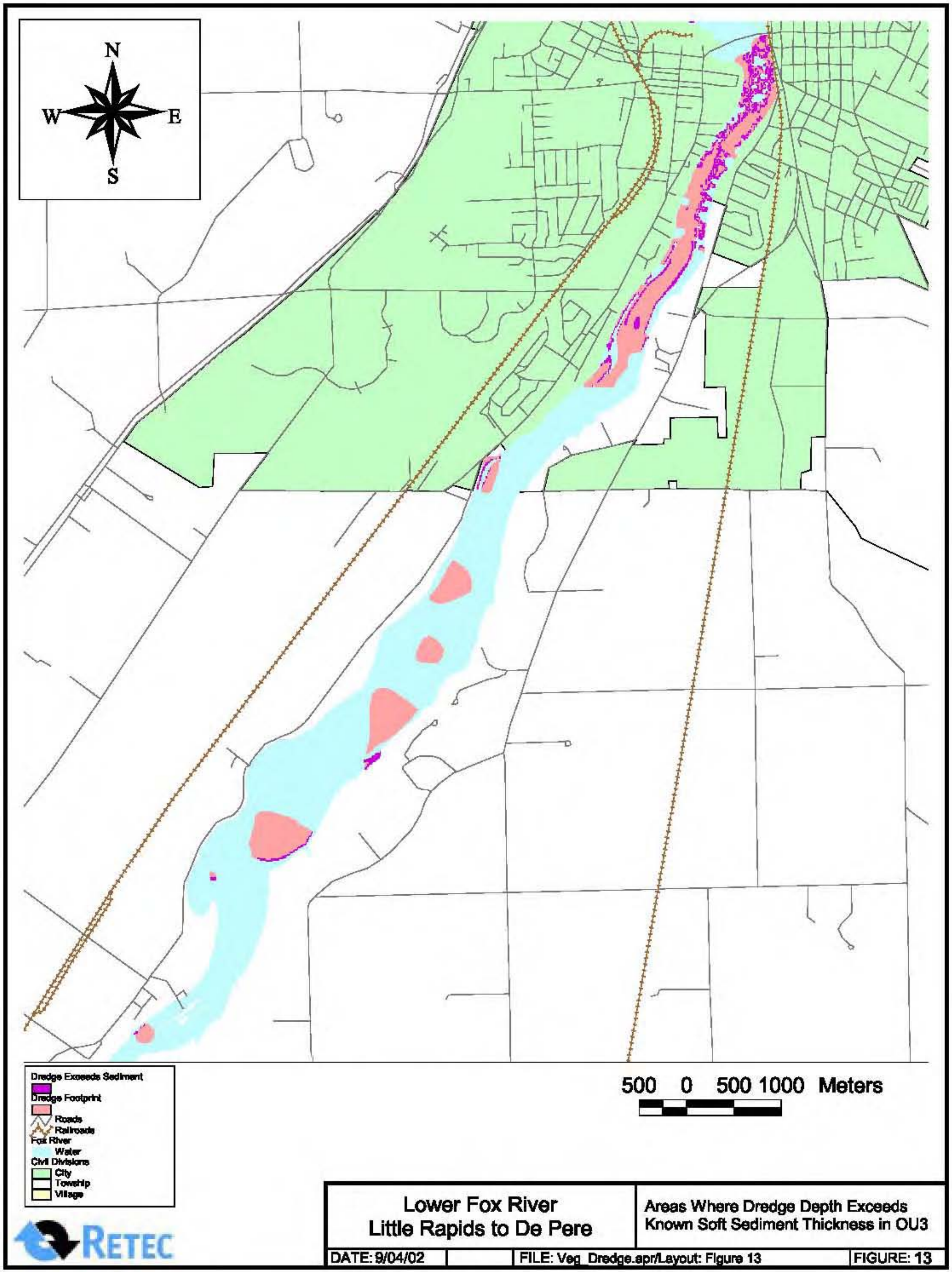
Dredge Exceeds Sediment
Dredge Footprint
Roads
Railroads
Fox River
Water
Civil Divisions
City
Township
Village
500 0 500 1000 Meters
RETEC
Lower Fox River
Little Lake Butte des Morts
Areas where Dredge Depth exceeds known Soft Sediment Thickness (1K PPB)
DATE: 8/30/02
FILE: Veg_Dredge.apr/Layout: Figure 12
FIGURE: 12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Dredge Exceeds Sediment
Dredge Footprint
Roads
Railroads
Fox River
Water
Civil Divisions
City
Township
Village
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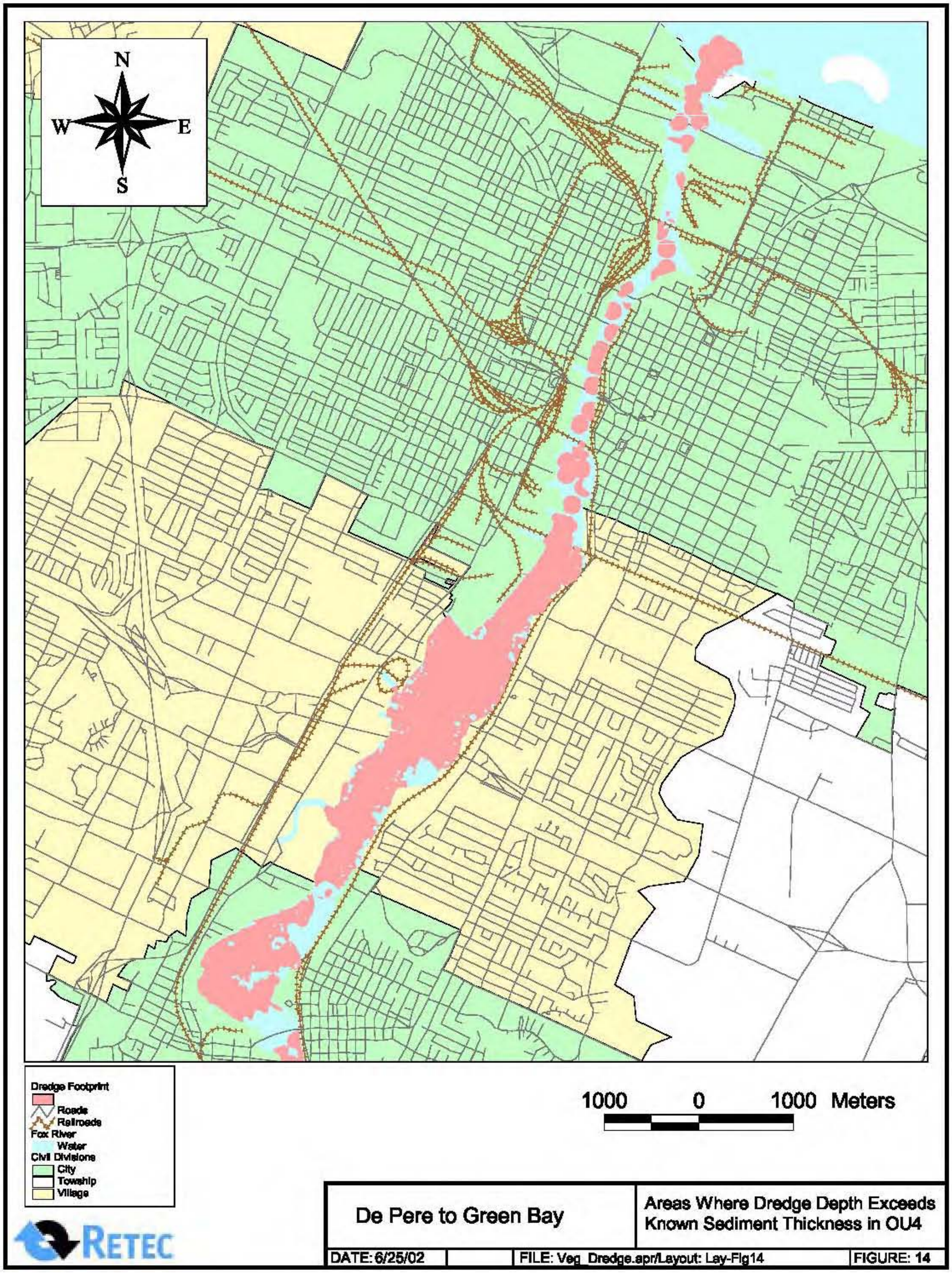
RETEC
Lower Fox River
Little Rapids to De Pere
Areas Where Dredge Depth Exceeds Known Soft Sediment Thickness in OU3
DATE: 9/04/02
FILE: Veg_Dredge.apr/Layout: Figure 13
FIGURE: 13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Dredge Footprint
Roads
Railroads
Fox River
Water
Civil Divisions
City
Township
Village
1000 0 1000 Meters
RETEC
De Pere to Green Bay
Areas Where Dredge Depth Exceeds Known Sediment Thickness in OU4
DATE: 6/25/02
FILE: Veg_Dredge.apr/Layout: Lay-Fig14
FIGURE: 14

As shown on Figure 12, the majority of the substrate predicted to change is in central Little Lake Butte des Morts. Substrate from a large, undivided dredging section in the northern part of the lake will remain unchanged, as will most of the dredging sections in the northern part of Little Lake Butte des Morts. In OU 3, anticipated substrate change is mostly on the edges of the dredge footprint at the downstream, or northern, end of the reach. Anticipated substrate change in OU 4 is scattered throughout the reach but is concentrated near the central and upstream/southern portions.

Almost one-third of the soft sediment in OU 4 targeted for dredging is anticipated to change to stiff, silty clay following dredging. Dredging for navigational purposes is currently performed by the USACE in OU 4, likely limiting the thickness of soft sediment remaining in the reach. This reach is located below each of the other three reaches and receives additional sediment loads and invertebrates present in the drift from each upstream area. It is likely that sediment deposited from upstream areas will accumulate in backwater and cove areas first and eventually fill in the new, exposed substrate. More than half of the substrate in OU 4 and 80 percent of the substrate in OU 1 and OU 3 will remain unchanged following dredging, allowing quick recolonization of invertebrates to take place.

### 4.1.2 Removal or Isolation Effects on the Lower Fox River Food Web

Either of the proposed remedies, removal or isolation (dredging or capping), will have no overall impact to the food web. The food chain of the Lower Fox River may be referred to as a pelagic food chain due to the heavy dependence on water column organisms (RETEC, 2002a; Exponent, 1999; LTI Environmental Engineering, 1999), and therefore will likely be unaffected by removal or isolation of benthic organisms. The fish in the Lower Fox River are primarily dependent on water column organisms, and although benthic organisms may be temporarily unavailable, the majority of the food organisms will be present in areas near dredging activities.

The time of year of disturbance may be important to fish populations. Fluctuations in benthic invertebrate, algal, zooplankton, and fish abundances occur seasonally. Blooms of algal populations and resultant zooplankton communities usually occur in spring. Fish species have been found to commonly switch to alternative prey items during initial phases of recovery (Kingsbury and Kreutzweiser, 1987; Warner and Fenderson, 1962). For example, fish estimated to consume oligochaetes and chironomids may be forced to consume zooplankton if oligochaetes and chironomids are temporarily unavailable due to dredging or capping activities.

Secondary consumers like shiners, shad, and perch almost exclusively depend on phytoplankton and zooplankton as food sources. Higher consumers like walleye and rainbow smelt consume shiner and shad. Carp appear to be largely dependent on benthic invertebrates, but have demonstrated flexibility in their diets. Zooplankton are estimated to make up almost half of their diet as adults (Scott and Crossman, 1973). Based on the evidence supporting the dependence on a pelagic based food chain, diets of fishes in the Lower Fox River are likely to be unaffected by dredging or capping activities.

Hydraulic dredging has been used as a means of removing nutrients contained in the sediment in Lake Okeechobee in Florida (SFWMD, 2002). It is thought that dredging decreased the amount of nutrients that could be resuspended to the water column, in turn decreasing the likelihood of algae blooms that normally worsen water clarity. Algae blooms of phytoplankton and filamentous algae can reduce light penetration into the water column, making it more difficult for SAV to establish.

### 4.1.3 Other Dredging Issues

#### *Suspended Sediments*

Suspended sediments can cause lethal, sublethal, and/or behavioral effects to aquatic receptors. The Lower Fox River is a slow-moving river clouded by naturally occurring suspended sediments; however, dredging or cap placement operations could cause elevated suspended sediment concentrations. The effects of suspended material are summarized for primary producers, invertebrates, and fish in LaSalle et al. (1991); Table 10 highlights causal factors and potential deleterious effects as presented in this paper.

In the dredging pilot project at SMU 56/57, silt curtains were used to prevent the movement of suspended solids downstream. The average turbidity inside the silt curtain was slightly higher than outside the silt curtain (Appendix B, RETEC, 2002b). Also, average turbidity measurements outside of the silt curtain were not appreciably different between upstream and downstream locations. Suspended solids resulting from dredging at SMU 56/57 has minimal effect on organisms located inside and outside the silt curtain (Appendix B, RETEC, 2002b).

Dredging will likely have little to no affect on the phytoplankton and zooplankton communities due to the high amount of suspended sediments already present in the Lower Fox River. Additional suspended material can reduce photosynthetic activity due to the interference of light penetration, but additional nutrients may be released to the water column as a result of dredging, thus serving to increase the plankton biomass (Stern and Stickle, 1978). Because of the dependence on water column organisms, this effect is likely to provide additional food resources to the aquatic and benthic community of the Lower Fox River.

Dredging should not cause fish present in the Lower Fox River to be subjected to higher levels of suspended sediments than are already present in the River. Many studies have been devoted to the effects of suspended material on the reproduction, growth, and development of fishes. Extensive general and supplementary bibliographies on the effects to fish are provided in Plumb (1973). Schubel and Wang (1973) found that in a relatively well-mixed environments, concentrations of natural fine-grained suspended sediment up to about 500 mg/L would not affect hatching success of yellow perch, white perch, striped bass, or alewife. Auld and Schubel (1978) found that survival was reduced above 500 mg/L for yellow perch and striped bass and above 100 mg/L for alewife. (See Table 3 for background and maximum concentrations for Lower Fox River demonstration projects N and SMU 56/57.)

## TABLE 10 DREDGING EFFECTS

| Organism | Life Stage | Causal Factors | Effect |
|---|---|---|---|
| Fish | Eggs | ▪ Entrainment and mechanical abrasion of egg and larvae<br>▪ Reduction of available light<br>▪ Sorption of contaminants carried by sediments<br>▪ Interference with feeding<br>▪ Smothering<br>▪ Increased exposure to toxic compounds | ▪ Hatching success<br>▪ Delayed and/or asynchrous development |
| | Larvae | ▪ Loss of chorion protection<br>▪ Adhesion of particles to epidermis impairing respiration<br>▪ Abrasive damage to gills and epidermis<br>▪ Entrainment<br>▪ Increased exposure to toxic compounds | ▪ Mortality with reduced survival occurring at ≥ 100 – 500 mg/L for some species |
| | Adults | ▪ Interference with respiration and feeding<br>▪ Increased exposure to toxic compounds | ▪ Behavioral distress<br>▪ Disrupted gill tissue and increased mucous production in white perch at 650 mg/L (Sherk et al., 1975)<br>▪ Lethal turbidity > 16,500 mg/L for 16 species of fresh water fish (Wallen, 1951) |
| Benthic Invertebrates | | ▪ Burial<br>▪ Changes in grain size, slope, compaction<br>▪ Blocking of chemical cues (i.e., pheromones)<br>▪ Respiration and feeding interference<br>▪ Decreased light interfering with larval settling site cues<br>▪ Increased exposure to toxic compounds | ▪ Mortality<br>▪ Interference with reproduction and recruitment |
| Algae and SAV | | ▪ Decreased light<br>▪ Respiration interference<br>▪ Increased exposure to toxic compounds | ▪ Reduced photosynthetic capabilities<br>▪ Variable responses to increased exposure toxic compounds |

#### *FISH AVOIDANCE/ENTRAINMENT*

Fish are usually quite mobile, allowing them to avoid the disturbance and actively seek out undisturbed areas containing refugia. Sufficient refugia located in undredged areas (areas targeted in the future or untargeted areas) should be available as fish avoid dredging activities. However, fish eggs may be susceptible to entrainment by suction dredges when they come in contact with the suction field around the intake pipe (McNair and Banks, 1986).

Small numbers of fish entrainment can occur during dredging activities. Entrainment rates in Grays Harbor range from 0.001 to 0.135 fish per cubic yard (fish/cy) (Armstrong et al., 1981) and from 0.001 to 0.38 fish/cy for material dredged in the mouth of the

Columbia River, Oregon, and Washington (Larson and Moehl, 1990). For several fish species studied in Grays Harbor, Washington, Armstrong et al. (1981) found large and small fish to be entrained in similar proportions, indicating that large fish did not actively avoid the dredge any more effectively than smaller fish. None of the fish that were entrained is a species found in the Lower Fox River due to the estuarine environment of the study areas. However, the potential for entrainment may increase if operations occur during migration periods in heavily used narrow-channel habitats (Lasalle et al., 1991), although narrow-channel habitats of the Lower Fox River typically contain faster flowing water and are composed primarily of harder substrates not targeted for dredging.

### 4.1.4 Reestablishment Following Removal or Isolation

Direct removal of sediment or placement of a cap would likely alter the benthic invertebrate community. The pelagic food web of the Lower Fox River will likely not be affected by dredging or capping; however, fish spawning habitat (as discussed above) and benthic invertebrate community composition could be affected. Benthic organisms may be removed or buried, and substrate type may change. These issues and factors influencing recovery are discussed further below.

#### *SUMMARY OF RECOVERY FOLLOWING DREDGING IN THE LOWER FOX RIVER*

The Lower Fox River aquatic trophic structure is largely dependent on water column organisms, however, benthic invertebrates like oligochaetes and chironomids provide some food for several species of fish and birds. The large dependence of the Lower Fox River community on water column organisms mitigates the effect of depressed benthic invertebrate populations as a result of dredging or capping. Fish are generally able to avoid dredging activities and relocate to habitat suitable for their feeding and reproductive needs. Fish present in the Lower Fox River already migrate to reaches with suitable habitat for spawning or to escape seasonally unfavorable temperature and dissolved oxygen concentrations (Hynes, 1970). Fish populations will return to disturbed areas previously occupied as benthic invertebrate communities reestablish. Evidence collected from pilot studies indicates that recovery of benthic invertebrates is rapid following sediment removal.

Many upstream invertebrate sources are present in the Lower Fox River. Surveys conducted throughout the entire reach of Little Lake Butte des Morts and in OUs 2, 3, and 4 have indicated that chironomids and oligochaetes are the most prevalent organisms throughout the entire River (IPS, 1993a, 1993b, 2000a, 2000b, 2000c; WDNR, 1996). The dredging footprint shown on Figure 9 indicates areas that are not targeted for dredging in Little Lake Butte des Morts. The extended dredging schedule will also allow for organisms within the 1-ppm footprint yet to be dredged to serve as source populations for adjacent areas already dredged. The types and proximities of undisturbed areas near the dredged areas will likely provide substantial sources for recolonization. The areas not proposed for dredging have more coarse substrates that generally host more diverse benthic invertebrate populations. It is highly probable that these organisms will migrate to dredged areas as part of the drift due to the consistent populations present in Lake Winnebago and OU 2.

Chironomids are a major component of the drift (Waters, 1972). In addition to drift, chironomids, which have one or more generations per year in a population, will likely also utilize aerial colonization pathways (Brundin, 1967). Substantial evidence is present to indicate that chironomids will recolonize the disturbed area. Chironomids have been found to be some of the earliest colonizers in experiments in streams (Waters, 1964; Gray and Fisher, 1981). New stream channels devoid of any invertebrate organisms appear to be quickly colonized by chironomids (Malmqvist et al., 1991). They recovered quickly in the lowland River Hull in areas with and without the establishment of aquatic vegetation following dredging (Pearson, 1984). In an experiment of defaunated sediment in Lake Erie, one species of chironomid and oligochaete established at abundances of two to seven times their natural abundances when compared to the nearby undisturbed community within 40 days; however, their abundances decreased later (Soster and McCall, 1990). Other chironomids reached their natural abundances quickly but did not exceed them.

In SMU 56/57, oligochaetes and chironomids appear to recolonize quickly despite shifts to substrate with greater proportions of clays and silts. Areas of sediment where benthic invertebrates were completely eliminated recovered within 9 months with an increased proportion of oligochaetes and increased numbers of both oligochaetes and chironomids (IPS, 2000c). In several of the dredging case studies, oligochaetes recolonized to levels greater than before dredging. In Wisconsin spring ponds, dredging removed the soft, organic sediment, exposing marl substrate and allowing oligochaetes to reestablish quickly and in much greater numbers than originally present (Carline and Brynildson, 1977). Considering the information contained in the case studies, regardless of the substrate change, oligochaetes and chironomids will quickly and fully reestablish.

### *Summary of Recovery Following Capping in the Lower Fox River*

The effects of capping on the Lower Fox River habitat and benthic macroinvertebrate community are similar to that of dredging. It may even have a more significant effect on the community because of the distinct change in substrate. The combinations of sand and gravel in proposed caps have low organic carbon due to the isolation of detritus already deposited and decomposing in the original sediment. The most common burrowing organisms like chironomids and oligochaetes depend on organic material for food. Chironomids are detritovores that depend on organic material in their first instar, but many become carnivorous as they grow older, with their diet being highly variable and opportunistic (Kajak and Dusoge, 1970). Oligochaetes are widespread but thrive in muds rich in organic matter (Poddubnaya, 1979).

Oligochaetes typically become more common in relation to chironomids as lakes become more productive, or eutrophic (Wetzel, 1983). More productive lakes contain added organic matter in the form of phytoplankton, vegetation, and algae that decomposes to form organic sediment. The addition of a sand and gravel cap low in organic carbon and detritus would likely provide a substrate unsuitable for chironomid and oligochaete establishment until organic rich sediment could be deposited after the cap was laid. This occurred following shifts in substrate to a sand cap in the highly productive Inlet Basin of Soda Lake in Wyoming, allowing colonization of oligochaetes and chironomids to reach levels similar to uncapped areas of the lake (ThermoRetec, 2001).

Many chironomids and oligochaetes also live on and around SAV. Because of the lack of organic material in a potential sand or gravel cap, SAV will likely not reestablish in areas where it was present prior to dredging until sufficient organic material accumulates on the cap. Seeds contained in the drift may settle in the sand or gravel cap; however, they are less likely to settle and stick in the non-organic substrate. Chironomids and oligochaetes will be present in lower abundance where SAV beds were previously present, decreasing the possibility that adult and juvenile fish will inhabit the area because of deficiencies in cover and food.

One of the limits imposed on potential capping sites within the River was that new carp spawning habitat not be created by increasing lake bottom elevations (see *White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River*).

# 5 CONCLUSION

The key points contained in this report are as follows:

- Potential impacts to habitat should be a consideration when selecting remedial actions, but restoration is not an RAO.

  In the case of the Lower Fox River, the major habitat considerations that emerge are a potential change in substrate type for benthic organisms, potential loss of valuable marshland, and potential positive or negative impacts to spawning habitat for fish species. These potential impacts are discussed more below, but the salient point is that habitat is only a consideration, not an objective. RAOs, in the FS, were set to govern the eventual outcome of remedial actions on the River. Habitat restoration is a function of a separate activity being conducted under the NRDA settlement.

- Dredging and capping, both locally and nationally, have been shown to have minimal impact on aquatic communities.

  The key consideration for any remedial action is that the food chain of the Lower Fox River is pelagic, or based on water column organisms. Changing the substrate through either dredging or capping will not cause any appreciable change in the food chain production.

  Dredging sediments in the Lower Fox River may cause habitat changes, however, these effects are temporary and only mildly affect the organisms currently living in the Lower Fox River. In the case of Deposit N, the residual habitat 2 years after dredging included some new sediment, but was largely well scoured and included larger, cobble-like material. In the case of SMU 56/57, the benthic recovery was very rapid, and within 2 years there was 5 feet of sediment accumulation.

  There are no caps placed in any riverine system with demonstrated, long-term monitoring of effectiveness anywhere in the world, so conclusions about the ecological effects of capping can only be inferred from marine-placed caps, or in the relatively few and recent freshwater lake cap systems. Any cap placed within the Lower Fox River will alter the benthic community, but its long-term effect will be dependent upon whether the area is a depositional or scour environment.

- Both dredging and capping have the potential to resuspend sediments, but the levels of resuspended solids and PCBs are lower than those naturally occurring on the Lower Fox River.

  Numerous national and international studies confirm that the short-term effects of resuspension are negligible. The longer-term effects of PCBs transported downstream are covered in a separate White Paper, but are considered to be minor, relative to the effects of leaving existing PCBs in place.

- Benthic invertebrates are in low diversity in the Lower Fox River and, as evidenced by the case studies provided, recovery may occur quickly in depositional areas of the Lower Fox River following dredging activities.

  Areas of scour may take longer to recover to pre-dredge conditions. Capping will alter the local benthic communities over the short term, given the need to provide final armor covering in any option. Caps may enhance, or depress local benthic production, depending upon the final substrate selected and whether the environment is depositional or scour. Over longer periods, sediment loads in depositional areas will fill in over the gravel or cobble armor layers, restoring pre-action benthic substrate conditions.

- Marsh habitat is an important and sparse asset on the Lower Fox River. Any remedial alternative should weigh the environmental risks from PCBs left in place to the risks of loss of habitat.

  There are very few areas where rooted SAV still exist within the Lower Fox River system. The current dredging or capping proposals would in some cases negatively impact these marshes. Where these exist, consideration should be given to the relative risk of leaving PCBs in place, allowing natural attenuation to occur, against the risk of loss of habitat. In Little Lake Butte des Morts, the marshland around Stroebe Island has been identified by the WDNR as a valuable spawning habitat for bluegill, sunfish, and bass, and the last remnant of northern pike spawning ground; and should not be a part of any ultimate removal or capping action.

  While PCBs have been measured above the RAL (1 ppm) in a relatively small area proximal to those wetlands (Deposit F), careful consideration should be made as to how, or if those should be managed. By contrast, a bed of water lilies does exist over Deposit A, where concentrations have been reported in the tens to hundreds of ppm.

  At these levels, the consideration should be for removal to manage ecological and human health risks from PCB exposure, and to plan for a restoration activity under the NRDA.

  Consideration also should be given to whether the observed SAV is actually valuable habitat, or an undesired exotic species. Again, within Little Lake Butte des Morts a considerable amount of the acreage identified in other reports as SAV is in fact Eurasian water milfoil, an exotic and/or eutrophic species that adversely affects both the benthic invertebrate and fish communities.

- Fish will not be affected by any of the proposed remedial alternatives.

  Fish are likely to neither be positively or negatively impacted by the dredging or capping remedial alternatives currently under consideration. Studies conducted by the USACE and others have repeatedly documented that fish are mobile species that will avoid disturbed areas and can reestablish in other readily available, suitable habitat. Successful management of fish spawning periods has been accomplished for many states and dredging projects by setting seasonal restrictions. Furthermore, case studies in Wisconsin suggest that removal of PCB-contaminated sediments may at least temporarily enhance the habitat by removing phosphorus and nitrogen that contribute to eutrophication in the River.

  Finally, critical habitat for desired game species such as walleye or bass on the Lower Fox River are outside of the areas proposed for removal.

- The type of habitat enhancements consistently called for by WDNR and the Proposed Plan are those that would support the diversification of the fish assemblages within the River and the creation of more nearshore, shallow littoral habitat.

  The Lower Fox River already supports a world-class walleye fishery, and the spawning and nursery areas for those fish are not affected by proposed removal operations, and not enhanced by armoring proposals for capping.

  Capping likely will have similar effects of dredging on aquatic vegetation and benthic invertebrate and fish communities; however, recovery of benthic invertebrate communities likely will be slower than recovery following dredging due to decreased organic content of the sediment.

  Benthic invertebrates are in low diversity in the Lower Fox River and, as evidenced by the case studies provided, will recover quickly in the Lower Fox River following dredging activities.

  SAV is only present in 29.9 percent of Little Lake Butte des Morts, much of which is not targeted for dredging, which provides sufficient cover and spawning habitat before, during, and after dredging.

- Multiple years of monitoring may be required to determine enhancements or detriments to the benthic habitat.

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# WHITE PAPER NO. 9 – REMEDIAL DECISION-MAKING FOR THE LOWER FOX RIVER/GREEN BAY REMEDIAL INVESTIGATION, FEASIBILITY STUDY, PROPOSED REMEDIAL ACTION PLAN, AND RECORD OF DECISION

***Response to a Comments on the***

## REMEDIAL INVESTIGATION FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN, FEASIBILITY STUDY FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN, PROPOSED REMEDIAL ACTION PLAN FOR THE LOWER FOX RIVER AND GREEN BAY, AND RECORD OF DECISION FOR THE LOWER FOX RIVER AND GREEN BAY


***This Document has been Prepared by***

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# ABSTRACT

This White Paper was prepared to document the remedial decision-making process for the Lower Fox River/Green Bay remedy selection. Development of the remedy selection was consistent with the evaluation process under United States Environmental Protection Agency (EPA) guidelines for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), National Research Council (NRC) guidance and EPA guidance for the management of polychlorinated biphenyl (PCB)-contaminated sites. This White Paper provides an overview of the supporting studies and tools used, the remedy evaluation process is described and discussed, and the remedy itself is briefly summarized. As shown in this White Paper, these tools together with the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a), *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) demonstrate the necessity to remediate, the availability of the remedial technology, and what may be reasonably expected from the remediation.

# 1 INTRODUCTION

In October 2001, the EPA and the Wisconsin Department of Natural Resources (WDNR) issued a Proposed Plan for addressing PCB contamination of the Lower Fox River and Green Bay. Development of the Proposed Plan and the selection of a remedy were the end result of an extensive evaluation process consistent with EPA guidelines for CERCLA projects in accordance with the federal National Contingency Plan (NCP). The remedy selection process was also consistent with NRC recommendations and other EPA guidance regarding the management of PCB-contaminated sediment sites. In addition to a site-specific RI/FS, selection of the proposed remedy was based on consideration of information provided by numerous supporting studies, tools, and public comments. Each of these supporting efforts contributed to the remedy evaluation process by providing a wide spectrum of analyses that consider the full range of possible outcomes for each remediation alternative. When collectively considered with the RI/FS, these tools:

1. Clearly demonstrate the need to remediate Lower Fox River contaminated sediments;

2. Show that technology exists to implement the selected remedy; and

3. Provide an understanding of what may be reasonably expected after the remedy is implemented.

An overview of the supporting studies contributing to the remedy evaluation process follows. After this overview, the remedy selection process is described and discussed. This White Paper then concludes with a brief summary of the selected remedy to restore the environmental quality of the Lower Fox River and Green Bay. The selected remedy is further described in the ROD for the Site.

# 2 OVERVIEW OF SUPPORTING STUDIES AND TOOLS

The types of supporting studies contributing to the development of the Proposed Plan for the Lower Fox River and Green Bay include:

1. Field studies delineating the extent and distribution of PCB in water, sediment, and fish;
2. Human health and ecological risk assessments;
3. Analyses of the spatial and temporal PCB concentration trends in sediment and fish;
4. Contaminated sediment depth and sediment bed stability;
5. Site-specific chemical transport and biota modeling;
6. Sediment remediation evaluation and demonstration projects; and
7. Public input into the remedy selection process.

### TABLE 1 LOWER FOX RIVER AND GREEN BAY REACH, ZONE AND OPERABLE UNIT DESCRIPTIONS

| Location | Description | Reach or Zone | Operable Unit |
|---|---|---|---|
| Lower Fox River | Little Lake Butte des Morts | Reach 1 | 1 |
| | Appleton to Little Rapids | Reach 2 | 2 |
| | Little Rapids to De Pere | Reach 3 | 3 |
| | De Pere to Green Bay | Reach 4/Zone 1 | 4 |
| Green Bay | Lower Fox River mouth to Little Tail Point | Zone 2 | 5 |
| | Little Tail Point to Chambers Island (West) | Zone 3a | |
| | Little Tail Point to Chambers Island (East) | Zone 3b | |
| | Chambers Island to Lake Michigan interface | Zone 4 | |

An overview of each of these items and the lessons learned from them are discussed below. In the RI/FS, the River and Bay were described in terms of reaches, zones, and Operable Units (OUs) as summarized in Table 1. The same terminology is also used in this White Paper.

## 2.1 FIELD STUDIES TO DELINEATE THE EXTENT AND DISTRIBUTION OF PCBS

PCB contamination of the Lower Fox River and Green Bay has been routinely monitored since the 1970s. Over the past 30 years, numerous field studies have been conducted to determine the extent and distribution of PCB contamination in the water, sediment, and fish of the Lower Fox River and Green Bay. In recent years, EPA, WDNR, the United States Geological Survey (USGS) and other groups have completed many field studies.

A summary of these studies is presented in Table 2. Since the release of the RI/FS and supporting documents, additional field sampling efforts have been completed.

The Fox River Database (FRDB), a site-specific data management system, was developed to compile all field data for the Lower Fox River/Green Bay project area. As part of database development, efforts were also undertaken to review data quality of all data was compiled into the database. More than 500,000 individual data records from over 35 different field studies are compiled into the FRDB. These data provide critical, site-specific information that was used to construct the RI, FS, risk assessments, and other supporting studies. Further information regarding FRDB development is presented in the *Data Management Summary Report* found in Appendix A of the RI (RETEC, 2002a).

Beyond the data in the FRDB, the overall project database includes contaminant release data for each major industrial and municipal wastewater facility that discharges to the Lower Fox River. The contaminant release records were further augmented by discharge information each facility submitted to the U.S. Department of Justice as part of Natural Resource Damage Assessment (NRDA) efforts. These records provide discharge information for the entire period of PCB use and occurrence in the Lower Fox River (1954–present). Further information regarding the releases of solids and PCBs is presented in Technical Memorandum 2d (WDNR, 1999a).

The sufficiency of the project database was examined by an EPA-sponsored review panel prior to the first release of the draft RI/FS in February 1999. This peer review found that the underlying database for the RI/FS and supporting projects was sufficient to determine the distribution of contaminants, support identification, and selection of a remedy using technologies employed at other large-scale sites, and select a remedy.

## TABLE 2 RECENT FIELD DATA COLLECTION EFFORTS FOR THE LOWER FOX RIVER AND GREEN BAY

| Year | Study | Media Sampled | | |
|---|---|---|---|---|
| | | Water | Sediment | Fish |
| 1989–1990 | EPA Green Bay Mass Balance Study (GBMBS) | ✓ | ✓ | ✓ |
| 1991–1994 | Deposit A RI/FS (WDNR) | ✓ | ✓ | |
| | USGS Follow-up to GBMBS | ✓ | | |
| | WDNR fish sampling | | | ✓ |
| 1994–1996 | RI/FS for select deposits (WDNR/GAS) | | ✓ | |
| | WDNR detailed sediment characterizations | | ✓ | |
| | WDNR fish sampling | | | ✓ |
| | EPA Lake Michigan Mass Balance Study (LMMBS) | ✓ | | |
| 1998–1999 | Deposit N Demonstration Project (WDNR) | ✓ [1] | ✓ [2] | |
| 1998 | RI/FS Supplemental Sampling (WDNR/RETEC) | ✓ | ✓ | ✓ |
| 1998–2001 | FRG:[3] selected portions of River and Bay | ✓ | ✓ | ✓ |
| | SMU 56/57 Demonstration Project | ✓ [1] | ✓ [2] | |

1 Water samples also include contaminant analyses for wastewater effluent.
2 Sediment samples also include contaminant analyses for dewatered sediments.

## 2.2 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

Human health and ecological risk assessments specific to the Lower Fox River and Green Bay were completed as part of RI/FS development. These studies examine the risks posed by exposure to PCBs and other chemicals of concern (COC). These studies consider the most significant means by which chemical exposures and risks occur. For PCBs in the Lower Fox River and Green Bay, the most significant risks to human health and wildlife occur though the consumption of contaminated fish. Human cancer risks were found to be 1,000 times greater than the $10^{-6}$ (one in one million) cancer risk management level and noncancer hazards were found to be 20 times greater than background risks. In addition to human health risk, ecological receptors such as fish-eating birds and mammals were also found to be at risk. The conclusion of these studies is that PCBs in the Lower Fox River and Green Bay present an unacceptable level of risk to human health and the ecosystem. The conclusion that PCBs are unacceptably high is also confirmed by the fact that fish consumption advisories have been in place for this region continuously since the risks were first evaluated in 1976. Further information regarding the risk assessments of PCBs is presented in the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c).

The risk assessment studies were examined by an FRG-sponsored peer review panel following the February 1999 release of the draft RI/FS. The peer review was conducted at the direction of the Association for the Environmental Health of Soils (AEHS). One significant peer review panel recommendation was the need to conduct a probabilistic risk assessment. In response to peer review panel recommendations, WDNR conducted a probabilistic risk assessment for human heath issues for the October 2001 release of the final RI/FS (see Appendix B of the BLRA entitled "Additional Evaluation of Exposure to PCBs in Fish from the Lower Fox River and Green Bay"). This assessment addresses concerns related to prenatal and developmental effects and more clearly states the basis for risk assumptions.

## 2.3 ANALYSES OF SPATIAL AND TEMPORAL PCB CONCENTRATION TRENDS IN SEDIMENT AND FISH

Analyses of spatial and temporal PCB concentration trends in sediment and fish were completed as part of RI/FS development. Identification of spatial and temporal trends in sediments is inherently difficult because field observations were collected at different horizontal locations, at different vertical locations relative to a fixed datum, and at different times. Clear identification of fish tissue PCB concentration trends is also difficult because fish are mobile and the predominant source of contaminants have shifted from wastewater discharges to sediments over time.

Due to the factors that complicate identification of trends, two studies employing different assumptions were conducted to examine sediment PCB trends. The first study (TMWL, 2002) assumes that, in the absence of a reference elevation datum, changes in

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[3] The FRG is a group of paper companies considered to be the potentially responsible parties (PRPs) for cleanup actions at this Site.

sediment bed elevation were negligible in order to estimate trends with depth in the sediment column. This study also assumed that none of the differences in observed PCB concentrations over time could be attributed to differences in laboratory procedures. The second study (see Appendix B of WDNR, 2001a) assumes that bed elevation changes are significant based on the results presented in Technical Memorandum 2g (WDNR, 1999b) and some of the differences in observed PCB concentrations over time are attributed to differences in laboratory procedures based on the results of independent inter-lab comparisons. Despite the wide differences in assumptions, these two studies both conclude that sediment PCB trends are highly variable (some decreasing, some constant, some increasing) and that trends cannot be assumed to be uniformly decreasing in future years.

To examine fish tissue PCB concentration trends, a study was conducted by TMWL (2002). This study assumes that fish experience PCB exposures in the area proximate to their collection location and that none of the differences in observed PCB concentrations over time could be attributed to differences in laboratory procedures. To account for differences in exposure regimes over time, contemporary fish tissue PCB concentration trends were segregated from historical trends by a "breakpoint." The years used as breakpoints range between the year when the last wastewater discharger to the River installed improved treatment facilities (P.H. Glatfelter Company in August 1979) to a year when residual PCB discharges were reduced to very small levels (the mid- to late 1980s). Years before the breakpoint represent a period when both point source discharges and sediments may have affected fish tissue PCB concentrations. Years after the breakpoint represent a period when only sediments are believed to have affected fish PCB burdens. This study concludes that in recent years, the rates at which fish tissue PCB levels have declined is significantly less than the historical period where ongoing PCB discharges occurred.

## 2.4 CONTAMINATED SEDIMENT DEPTH AND SEDIMENT BED STABILITY

Analyses of contaminated sediment depth and sediment bed stability were completed as part of RI/FS development. These studies examine the depths to which contaminants occur in the sediment column of the River and the stability of the sediment bed. These studies provide information needed to evaluate whether sediments contaminated with PCBs may be diluted by natural burial or contribute to risks in-place (by mixing) or elsewhere (by transport). Additional studies were also completed by EPA (*White Paper No. 3 – Fox River Bathymetric Survey Analysis*, 2002) and for the FRG (LTI, 2002) as part of independent efforts.

In the Lower Fox River, PCBs have been observed more than 5 meters (16 feet) below the sediment-water interface at some locations.[4] Based on the observations compiled in the FRDB and additional information regarding the thickness of Lower Fox River sediments, the volumetric extent and distribution of PCBs in the sediment column of the river was estimated in Technical Memorandum 2e and follow-up efforts (WDNR, 1999c, 2000a). As described in the RI (RETEC, 2002a), in the River reaches between Lake

[4] This condition was observed in the area around SMU 56/57 prior to the start of the pilot project for that site.

Winnebago and De Pere (OUs 1–3), more than 97 percent of the PCB mass is located within the upper 100 cm (3.3 feet) of sediment; and for the River reach between De Pere and Green Bay (OU 4), more than 90 percent of the PCB mass is within the upper 200 cm (6.6 feet) of sediment. A similar study was also completed for Green Bay (WDNR, 2001b).

The elevations of the sediment bed within the bounds of the River navigation channel between the De Pere dam and Green Bay are routinely monitored by the United States Army Corps of Engineers (USACE). Additional surveys have been completed by EPA and the USGS. Based on these data sources, three separate studies examining sediment bed elevations changes in sections of the River that have not been dredged in more than 30 years have been completed. As summarized in Technical Memorandum 2g (WDNR, 1999b) and follow-up efforts (see Section 4.2.2.1 of WDNR, 2001a), these surveys demonstrate that the sediment bed of the Lower Fox River is a very dynamic environment and that bed elevations can increase or decrease by more than 200 cm (6.6 feet) even during periods when there are very small net increases in bed elevation. These studies also concluded that the net rate of sediment accumulation can be very small compared to gross changes in bed elevation. A study completed by the EPA FIELDS Group (2001) reaches similar conclusions for undredged portions of the river channel. A third study completed for the FRG (LTI, 2002) that considered radioisotope patterns in sediment also concluded that sediment bed elevations between the De Pere dam and the River mouth may be decreasing in response to declining water levels in the Bay. These changes in sediment bed elevations are believed to result in episodic sediment mixing and downstream transport.

As described by WDNR (1999b, 2001a), it should be noted that the majority of the bed elevation data used for these studies was collected by the USACE as part of Class I surveys. The accuracy of these surveys was confirmed by field tests of the actual combined errors (equipment and procedural) of measurements. Data collected at the Sediment Management Unit (SMU) 56/57 demonstration site in August 1999 indicates that the combined vertical accuracy achieved by the USACE Kewaunee Office was approximately ±4 cm (WDNR, 1999d).

Several specific conclusions can be drawn from these studies. First, PCB contamination of Lower Fox River sediments is extensive. However, more than 97 percent of the PCB mass of OUs 1 through 3 resides in the upper 100 cm of the sediment column and more than 90 percent of the PCB mass in OU 4 resides in the upper 200 cm of sediment. Second, the sediment bed of the River can be a very dynamic environment. Large increases and decreases in sediment bed elevations were observed even for periods when there were very small net increases in bed elevation. Because natural rates of net sediment accumulation (burial) can be small, the potential to restore the River by natural burial (a passive PCB-contaminated sediment approach) may be limited. Third, the portions of the sediment column where most of the PCB mass in the sediment resides can be subject to episodic mixing and transport. Further, episodic mixing and transport of sediments between the De Pere dam and the River mouth (OU 4) may occur now and in the future in response to cyclical changes in water levels in Green Bay/Lake Michigan. When considered together, these studies indicate that the sediment bed of the Lower Fox

River is not necessarily a stable environmental for *in-situ* management of PCB-contaminated sediments and that the stability of the sediment bed can change over time in response to changes in conditions such as declining water levels.

Finally, it is worth noting that in terms of the dynamics of sediment bed elevation changes, the Lower Fox River is not unique. Similar ranges of bed elevation changes have been observed in the Sheboygan River (Wisconsin) (WDNR, 2000c). A recent study of bed mobility in the Sacramento River (California) also demonstrates that the bed of a river can be a very dynamic environment (Dinehart, 2002). In that study, the upper 30 cm of the sediment bed was typically found to be mobile (bedform transport) and moved downstream at rates that ranged from 0.43 to 2.01 meters per day (Dinehart, 2002).

## 2.5 SITE-SPECIFIC CHEMICAL TRANSPORT AND BIOTA MODELING

Site-specific PCB transport and food web bioaccumulation models were developed as part of the RI/FS. These models use mass balance and bioenergetics concepts to estimate the rates at which chemical concentrations in water, sediment, and biota (plankton, fish, etc.) change. For the RI/FS, four models were developed. A summary of these models is presented in Table 3. Brief descriptions of the models are presented in the sections that follow. Full descriptions of the models and all associated supporting studies are presented in the *Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin* (MDR) (WDNR and RETEC, 2002) that accompanies the RI/FS.

These models have been calibrated to conditions in the Lower Fox River and Green Bay. The primary use of the calibrated suite of models was to help estimate, in a comparative sense, what timeframe might be required to achieve acceptable fish tissue PCB concentrations for a series of different sediment action levels. Collectively, these modeling studies suggest: (1) that at present rates of change (the no action alternative) it may take many decades before PCB exposures and fish tissue PCB concentrations meet acceptable risk levels; (2) rates of PCB change (decline) may be improved by managing PCB levels in sediments; and (3) the degree to which rates of PCB decline may be improved is directly related to the extent of sediment PCB management efforts (more extensive management yields more rapid declines).

### TABLE 3 SITE-SPECIFIC CHEMICAL TRANSPORT AND BIOTA MODELS DEVELOPED FOR THE RI/FS

| Model | Sites | Use | MDR Location |
|---|---|---|---|
| wLFRM | Lower Fox River (OUs 1–4) | Water and Sediment Quality | Appendix B |
| GBTOXe | Green Bay (OU 5) | Water and Sediment Quality | Appendix C |
| FRFood | Lower Fox River (OUs 1–4) | Biota | Appendix D |
| GBFood | Lower Fox River (OU 4)<br>Green Bay (OU 5) | Biota | Appendix E |

The development history of these models and modeling approaches is well documented. Several generations of model development for the Lower Fox River and Green Bay system have been completed. The present generation of model applications presented in the MDR was based on information developed in conjunction with the FRG companies by a model evaluation workgroup (MEW) under the terms of a January 1997 agreement. A series of Technical Memoranda (TM) was prepared by the MEW. Each TM provides detailed analyses of a key aspect of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions. A more complete description of each TM is presented in the MDR (WDNR and RETEC, 2002). In addition to the TM, numerous publications, technical reports, and peer review documents describing aspects of the Whole Lower Fox River Model (wLFRM), Enhanced Green Bay Toxics Model (GBTOXe), Fox River Food Web Model (FRFood), and Green Bay Food Web Model (GBFood) development and performance are available. These include other documents: AGI (2000), Bierman et al. (1992), Connolly and Thomann (1992), Connolly et al. (1992), DePinto et al. (1993), Gobas (1993), Gobas et al. (1995), HydroQual (1995), HydroQual (1996), Steuer et al. (1995), Velleux and Endicott (1994), Tetra Tech, Inc. (2000), Velleux et al. (1995), Velleux et al. (1996), Velleux et al. (2001), and WDNR (1997).

### 2.5.1 Whole Lower Fox River Model (wLFRM)

The wLFRM was developed to examine the transport and fate of PCBs in the Lower Fox River (WDNR, 2001). The wLFRM is the result of numerous assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. The wLFRM was designed to estimate PCB concentrations in the water column and sediment of the Lower Fox River. PCBs and three types of solids in the water column and sediments were simulated. The model spatial domain is the entirety of the Lower Fox River from Lake Winnebago to the River mouth at Green Bay. This region was represented as 40 water column and 165 sediment stacks. Each sediment stack has up to 10 vertical layers depending on the thickness of sediments at a given location. The sediment layers represent biologically active sediments and deeper biologically inactive sediments. Mechanisms affecting PCB transport include: advection, dispersion, volatilization, erosion and deposition of particulate phases, porewater exchange of dissolved phases, and sediment bed armoring.

The wLFRM was calibrated using data collected as part of the EPA 1989–1990 GBMBS, the 1994–1995 LMMBS, and other field studies over the period 1989–1995. Once calibrated, the primary use of the wLFRM in the RI/FS was to conduct long-term (100-year) simulations of PCB transport and fate in the Lower Fox River for conditions ranging from no action to a series of sediment management action levels. Further information regarding the wLFRM is presented in the MDR (WDNR and RETEC, 2002).

It should be noted that development of the wLFRM for the RI/FS was based on information developed in conjunction with the FRG companies by the MEW and a peer review of model performance. The MEW prepared a series of TMs. Each TM provides detailed analyses of a key aspect of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions. A more complete description of each TM is presented in the MDR (WDNR and RETEC, 2002). In addition to MEW efforts, an FRG-sponsored peer review panel presented additional assessments of model performance (AGI, 2000). To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts.

### 2.5.2 Enhanced Green Bay Toxics Model (GBTOXe)

The GBTOXe was developed to examine the transport and fate of PCBs in Green Bay (HydroQual, 2001). GBTOXe is an enhanced version of the GBTOX model originally developed as part of the EPA GBMBS (Bierman et al., 1992; DePinto et al., 1993). Enhancements include finer spatial resolution and linkages to a hydrodynamics model (GBHYDRO) and a sediment transport model (GBSED) for Green Bay. GBTOXe was designed to estimate PCB concentrations in the water column and sediment of Green Bay. PCBs and three types of carbon in the water column and sediments were simulated. The carbon types considered are dissolved, biotic, and particulate detritus. The biotic and particulate detritus carbon types represent the portion of the suspended solids in the Bay with which PCBs may associate. The model spatial domain is the entirety of Green Bay from the Lower Fox River mouth to the Lake Michigan interface. This region was represented as 1,490 water column and 596 sediment segments. The water column has 10 vertical layers, each with 149 horizontal segments. The sediment layers represent biologically active sediments and deeper biologically inactive sediments. Mechanisms affecting PCB transport include: advection, dispersion, volatilization, erosion and deposition of particulate phases, porewater exchange of dissolved phases, and sediment bed armoring.

GBTOXe was calibrated using data collected as part of the 1989–1990 EPA GBMBS. The GBMBS provides the only comprehensive data for Green Bay water and sediment sufficient for model development. Once calibrated, the primary use of GBTOXe in the RI/FS was to conduct long-term (100-year) simulations of PCB transport and fate in Green Bay for conditions ranging from no action to a series of sediment management action levels. Further information regarding GBTOXe is presented in the MDR (WDNR and RETEC, 2002).

### 2.5.3 Fox River Food Web Model (FRFood)

The FRFood bioaccumulation model provides a mathematical description of PCB transfer within the food web of all four reaches of the Lower Fox River (OUs 1–4) and inner Green Bay (Zone 2). This model was designed to estimate PCB concentrations in the aquatic food web of the Lower Fox River (i.e., benthic organisms, phytoplankton, zooplankton, and fish) based on PCB concentrations in water and sediment. In addition to the River, FRFood also includes a portion of the Bay food web. This overlap is necessary because fish can freely move between the last reach of the River (De Pere to Green Bay) and the Bay. FRFood is functionally similar to the food web model for Green Bay (GBFood) described in Section 2.5.4. FRFood was also designed to estimate the average sediment PCB concentration needed to meet a specified target fish tissue PCB level. Each reach has a specified food web. The food web is represented as the primary energy and chemical transfer pathways from exposure sources (sediment and water) to fish species of interest. These pathways include: chemical uptake across the gill surface, chemical uptake from food by species-specific and age class-specific predator-prey relationships, chemical loss by excretion, and dilution by growth.

FRFood was calibrated using exposure concentrations defined by field data collected as part of the 1989–1990 EPA GBMBS and subsequent sampling efforts over the period

1989–1995 (RETEC, 2002c). Once calibrated, the primary uses of FRFood in the RI/FS were to: (1) estimate potential risk-based remedial cleanup levels, called sediment quality thresholds (SQTs); and (2) conduct long-term (100-year) simulations to estimate fish tissue concentrations for conditions ranging from no action to a series of sediment management action levels. For FRFood long-term simulations, exposure conditions were defined by wLFRM long-term simulation results. Further information regarding FRFood is presented in the MDR (WDNR and RETEC, 2002).

### 2.5.4 Green Bay Food Web Model (GBFood)

The GBFood bioaccumulation model provides a mathematical description of PCB transfer within the food web of last reach of the Lower Fox River (De Pere to Green Bay) (OU 4) (Zone 1) and all of Green Bay (OU 5) (Zones 2–4). This model was designed to estimate PCB concentrations in the aquatic food web of Green Bay (i.e., benthic organisms, phytoplankton, zooplankton, and fish) based on PCB concentrations in water and sediment. In addition to the Bay, GBFood also includes a portion of the River food web. This overlap is necessary because fish can freely move between the last reach of the River (De Pere to Green Bay) and the Bay. Each zone has a specified food web. The food web is represented as the primary energy and chemical transfer pathways from the exposure sources (sediment and water) to the fish species of interest. These pathways include: chemical uptake across the gill surface, chemical uptake from food by species-specific and age class-specific predator-prey relationships, chemical loss by excretion, and dilution by growth.

GBFood was calibrated to conditions defined by field data collected as part of the 1989–1990 EPA GBMBS (QEA, 2001) using exposures estimated by wLFRM and GBTOXe. Once calibrated, the primary uses of GBFood in the RI/FS were to conduct long-term (100-year) simulations to estimate fish tissue concentrations for conditions ranging from no action to a series of sediment management action levels. For GBFood long-term simulations, exposure conditions were defined by wLFRM and GBTOXe long-term simulation results. Further information regarding GBFood is presented in the MDR (WDNR and RETEC, 2002).

## 2.6 Sediment Remediation Evaluation and Demonstration Projects

A range of different PCB-contaminated sediment remediation approaches for the Lower Fox River was examined as part of the RI/FS. Passive and active methods for managing contaminated sediments were considered. Passive processes that can affect PCB risks include burial (dilution of PCB-contaminated sediment by the buildup of an overlying layer of cleaner sediments), dispersion (dilution of PCB-contaminated sediment through movement within the water column and the gradual settlement of this contaminated sediment), and dechlorination (detoxification by the removal of chlorine atoms from PCB molecules). Burial, dispersion, and dechlorination are processes that contribute to "natural recovery." The potential for burial of PCBs was examined as part of contaminated sediment depth and sediment bed stability studies. The potential for continued dispersion remains high as long as PCBs continue to remain at the sediment surface, which results in downstream contamination and movement of PCB mass into Green Bay. The potential for PCB dechlorination was examined as part of a dechlorination study described in Section 2.6.1. Active methods to manage PCBs include capping and dredging. Capping was examined as part of the FS (RETEC, 2002b). General aspects of dredging were examined as part of sediment technologies study described in Section 2.6.2.

In addition to the dechlorination and sediment technologies supporting studies, the results of two sediment remediation demonstration projects on the Lower Fox River were also considered in the RI/FS. Sediment removal demonstration projects were completed at two sites: Deposit N and SMU 56/57. These two projects provided information regarding insight on the technical and administrative feasibility of managing remediation projects for the Lower Fox River. In addition to providing information regarding the ability to complete environmental dredging projects on the Lower Fox River, the projects also provided information regarding were to: evaluate implementation issues (access agreements, insurance, site access, contracting, permits, and liability waivers and indemnification); conduct monitoring (operational, deposit mass balance, process mass balance, river transport, and air); and provide information on remediation prior to the initiation of full-scale work.

These demonstration projects showed communities in the Fox River Valley what dredging looked like and demonstrated that: (1) there were no community disruptions, (2) PCBs can be permanently removed from river, (3) PCB-contaminated sediments can be disposed in a local landfill, and (4) there was compliance with all permits and permit requirements. In addition, at the SMU 56/57 project, additional monitoring showed there were no resuspension problems from dredging and there is no risk from air releases from dredging. These projects conclusively demonstrated that successful dredging projects can be conducted on the Lower Fox River.

### 2.6.1 Natural Dechlorination

A PCB dechlorination study was conducted as part of the RI/FS. Dechlorination is the only potential means by which PCB toxicity may be reduced under natural conditions (passive management). The *Review of Natural PCB Degradation Processes in Sediments* (Dechlorination Study) (see Appendix D of RETEC, 2002b) showed that dechlorination does not occur where PCB concentrations are less than 30 mg/kg. While certain locations in the River exceed this threshold, PCB concentrations at most locations are less than 30 mg/kg. As a result, the study concludes that passive management of PCBs by dechlorination is not a reliable or effective means to reduce PCB risks for Lower Fox River sediments.

### 2.6.2 Sediment Technologies Memorandum

To assess concerns about the short-term and long-term effectiveness of environmental dredging as a remedial alternative, WDNR commissioned an evaluation of 20 environmental dredging case studies in the a study entitled *Sediment Technologies Memorandum for the Lower Fox River and Green Bay, Wisconsin*, which can be found in Appendix B of the FS (RETEC, 2002b). The study found that dredging to achieve a specific target goal (e.g., an elevation or a concentration) can be accomplished and that dredging in soft sediments can effectively remove contamination with minimal re-suspension and downstream transport of contaminants. The study also found that environmental dredging has been effective in reducing the risk to human health in several projects. The study also identified several recommendations including the need to identify a clear target goal, having adequate site-specific knowledge, determining acceptable risks during implementation, and developing an appropriate long-term monitoring plan to verify project success.

### 2.6.3 Deposit N

In 1998 and 1999, WDNR and EPA sponsored a project to remove PCB-contaminated sediment from Deposit N in the Lower Fox River. The primary objective of this project was to demonstrate that dredging could be performed in an environmentally safe and cost-effective manner to manage PCB-contaminated sediments in the Lower Fox River. The Deposit N site was approximately three acres in size and contained about 11,000 cubic yards (cy) of contaminated sediment with PCB concentrations as high as 186 milligrams per kilogram (mg/kg). Sixty-five percent of the sediment volume of Deposit N was targeted for removal. Approximately 8,200 cy of sediment were removed from the site, generating 6,500 tons of dewatered sediment that contained 112 total pounds of PCBs. The total material also included approximately 1,000 cy of sediment that was removed from Deposit O, another contaminated sediment site adjacent to Deposit N.

Monitoring data from the project showed that the River was protected during the dredging and that wastewater discharged back to the River complied with all permit conditions. The project also met design specifications such as the volume of sediment removed, sediment tonnage, and allowed thickness of residual sediments. In addition to the removal of PCBs from the site, other benefits of the project included opportunities for public outreach and education on the subject of environmental dredging. In assessing project success, it should be noted that Deposit N projects goals were to test the ability of a management effort to meet design specifications that focused on PCB mass removal rather than a concentration-based cleanup. A cost analysis of this project indicated that a significant portion of the funds was expended in pioneering efforts associated with the first PCB cleanup project on the Lower Fox River and the added winter construction expenses that were incurred to meet an accelerated construction schedule. Such added costs are not typical and would not necessarily be incurred with future projects.

### 2.6.4 SMU 56/57

One of the projects conducted under the January 1997 agreement with the FRG companies was a sediment remediation project. The objective of this effort was to design, implement, and monitor a project in the Lower Fox River downstream of the De Pere dam. In conjunction with WDNR, the FRG selected SMUs 56 and 57 (SMU 56/57) as the project site. The specific goal of this project was to remove 80,000 cy of PCB-contaminated sediment from the site. In late 1999, contractors and consultants under the direction to the FRG designed and implemented the project. Dewatered sediment was moved by truck to a landfill owned and operated by Fort James Corporation (now Georgia Pacific) for disposal. Due cold weather, ice, and other factors, the FRG stopped dredging operations after approximately 31,350 cy of sediments were removed from the River. Following the end of FRG efforts, Fort James Corporation agreed to complete the SMU 56/57 project in Spring 2000 and entered into an Administrative Order By Consent

(AOC) with EPA and the State of Wisconsin (Docket No. V-W-00-C-596). Under the terms of the AOC, Fort James funded and managed the project in 2000 with oversight from WDNR and EPA. Overall, the 1999 and 2000 efforts at SMU 56/57 resulted in the removal of approximately 2,070 pounds of PCBs from the River. In particular, the 2000 project efforts met all goals set forth in the AOC, and also met or exceeded project goals for sediment removal rates, dredge slurry solids, filter cake solids, and production rates that were set forth for the original effort managed by the FRG in 1999.

Like the Deposit N effort, monitoring data from SMU 56/57 project showed that the River was protected during the dredging and that wastewater discharged back to the River complied with all permit conditions. In addition, the project data showed that air releases of PCBs during dredging and handling are so small (essentially zero) such that there is no real risk associated with possible air releases of PCBs. The SMU 56/57 project also demonstrated the ability to use a local landfill for sediment disposal.

## 2.7 PUBLIC INPUT INTO THE SELECTION PROCESS

Comments from the general public and all stakeholders such as municipalities and the FRG have been received throughout the development process for the RI/FS and Proposed Plan. At each stage of development, the RI/FS and Proposed Plan have been shaped by comments provided to EPA and WDNR. For example, WDNR and EPA received numerous comments regarding the draft RI/FS that was released in April 1999. In response to those comments, the scope of the RI/FS was expanded to include all of Green Bay and numerous supporting studies were completed to more fully consider remediation options for the Site. Following the release of the RI/FS in October 2001, WDNR and EPA again received numerous comments. It should be noted that a formal period for submission of comments was provided and that the time period for comments far exceeded the 30-day minimum time required by the NCP under CERCLA. For example, the comment period following the October 2001 release of the RI/FS and the Proposed Plan lasted more than 3 months. To finalize the RI/FS, WDNR and EPA have prepared a Responsiveness Summary to document responses to comments regarding the RI/FS that were received during the January 2002 formal comment period.

In addition to formal comment periods, WDNR and EPA have participated in an ongoing process for community involvement that has included numerous public meetings since the summer of 1997. These meetings have focused on a variety of topics, including cleanup and restoration activities, the status of pilot projects, fish consumption advisories, and the draft RI/FS. Over this period, WDNR and EPA staff members have made presentations for various community groups. WDNR and EPA also publish a bimonthly newsletter, the *Fox River Current*, which is mailed to over 10,000 addresses. These communication efforts are consistent with National Academy of Science (NAS) recommendations that risk management of PCB-contaminated sediment sites include early, continuous, and frequent involvement of affected parties.

Beyond comment periods and communication efforts, it should be noted that long before formal RI/FS efforts were initiated, the public and the regulated community have been involved and contributed to the remedy selection process for the Lower Fox River. In 1993, a group of paper mills and municipalities approached WDNR to establish a cooperative process for resolving PCB-contaminated sediment issues. The outcome was the formation of the Fox River Coalition, a private-public partnership of businesses, state, and local officials, environmentalists, and others groups committed to improving the quality of the Lower Fox River. The Coalition focused on the technical, financial, and administrative issues that would need to be resolved to achieve a whole river cleanup. The Coalition helped conduct several projects including an RI/FS for several sediment deposits upstream of the De Pere dam, mapping of sediment contamination downstream of the De Pere dam, collection of sediment cores from 113 locations between De Pere and Green Bay, and funding for a portion of the Deposit N pilot project. The results of these Coalition efforts are fully integrated into the present RI/FS.

# 3 SELECTION OF THE PROPOSED REMEDY

The process used by WDNR and EPA to select the proposed remedy was well-defined and consistent with EPA guidelines for projects conducted under CERCLA. The FS describes a series of alternatives to manage risks attributable to PCBs and other contaminants of concern for each management area of the Site. The Lower Fox River and Green Bay Site is divided into five OUs. These alternatives examined include an array of action levels that range from natural recovery (no action) to successively greater levels of management (lower target residual levels of PCBs) for each OU. A list of the OUs for the Site was presented in Table 1. Each remedial action level (RAL) was evaluated by well-established criteria within the context of a risk management goal. For the Lower Fox River and Green Bay Site, WDNR and EPA established the risk management goal as the elimination of fish consumption advisories for high-intake fish consumers within 10 years and recreational anglers within 30 years.

Consistent with CERCLA guidelines, nine criteria were used to evaluate alternatives. These nine criteria are summarized in Table 4. As part of this evaluation process, the tradeoffs between the degree to which a remedy could reach the risk management goal (Threshold Criteria), the scope and nature of the remedy (Balancing Criteria), and its acceptability (Regulatory Agency and Community Criteria) were considered. The proposed remedy selected by this process represents an optimized combination of the nine criteria in consideration of the overall management goal.

### TABLE 4 CERCLA CRITERIA USED TO EVALUATE REMEDIATION ALTERNATIVES

| Category | Criteria |
|---|---|
| Threshold Criteria | 1. Overall protection of human health and the environment<br>2. Compliance with applicable or relevant and appropriate requirements (ARARs) |
| Balancing Criteria | 3. Long-term effectiveness and permanence<br>4. Reduction of toxicity, mobility, and volume through treatment<br>5. Short-term effectiveness<br>6. Implementability<br>7. Cost |
| Regulatory Agency and Community Criteria | 8. Agency acceptance<br>9. Community acceptance |

A key feature of the remedy selection process for the Lower Fox River and Green Bay was the use of multiple lines of information to determine whether an alternative would comply with the criteria. Each of the supporting studies developed for the RI/FS contributed to remedy selection process. Supporting studies were developed using different assumptions in order to provide the widest possible perspective to inform the remedy selection process. The diversity of perspective that each study provides makes the RI/FS more complete and the Proposed Plan more sound because analyses were not restricted to approaches that favored any individual outcome (i.e., no action vs. action).

In contrast, approaches advocated by others appear to presuppose no action is the only viable alternative.

Under CERCLA, the ROD is the document where a remedy for a site is selected. At this time, WDNR and EPA have issued an ROD for OU 1 (Little Lake Butte des Morts) and OU 2 (Appleton to Little Rapids). The discussion that follows focuses on how the selected remedy satisfies the nine criteria for OUs 1 and 2. While specific to OUs 1 and 2, it is important to note that the remedy selection process described is applicable to the remaining three OUs for the Site.

## 3.1 THRESHOLD CRITERIA

As part of remedy evaluation, the ability of each alternative to meet Threshold Criteria was considered. Protection of human health and the environment was evaluated by considering the risk associated with PCBs remaining in surface sediment for each alternative. For this evaluation, the following five conditions were examined:

1. Surface-weighted average residual PCB concentrations in surface sediments;
2. Average PCB concentrations in surface water;
3. The estimated number of years needed to eliminate fish consumption advisories for PCBs;
4. The estimated number of years required to reach surface sediment PCB concentration protective of fish and other biota; and
5. PCB loadings to downstream areas and total mass remediated.

Compliance with applicable or relevant and appropriate requirements (ARARs) was evaluated by considering whether an alternative can meet appropriate federal and state requirements, standards, criteria, and limitations as required by Section 121(d) of CERCLA and NCP § 300.430(f)(1)(ii)(B). Compliance with ARARs is required, unless waived under CERCLA Section 121(d)(4). ARARs are discussed in detail in Section 4 and Section 9 of the FS (RETEC, 2002b) and are also presented in the ROD.

The primary risk to human health is through consumption of fish. The primary risk to the environment is the bioaccumulation of PCBs from the consumption of fish or, for invertebrates, the direct ingestion/consumption of sediment. The sediments of the River and Bay are PCB-contaminated and are the predominant source of PCBs in the system. On a Site-wide basis, human cancer risks were found to be 1,000 times greater than the $10^{-6}$ (one in one million) cancer risk management level and noncancer hazards were found to be 20 times greater than background risks. Wildlife such as fish-eating birds and mammals were also found to have unacceptably high risk levels. The conclusion that PCBs are unacceptably high is also confirmed by the fact that fish consumption advisories have been in place for this region continuously since the risks were first evaluated in 1976. For both OUs 1 and 2, risks associated with existing conditions in the

Lower Fox River exceed acceptable limits described in risk assessment studies (RETEC, 2002c).

Protection of human health and the environment was evaluated by residual risk in surface sediment using five lines of evidence that include: residual PCB concentrations in surficial sediment using surface-weighted averaging after completion of a remedy; average PCB concentrations in surface water; the projected number of years required to reach safe consumption of fish; the projected number of years required to reach a surface sediment concentration protective of fish or other biota; and PCB loadings to downstream areas and total mass contained or removed.

As described in the FS, increasing levels of sediment management are expected to reduce residual surface sediment PCB concentrations, decrease average PCB concentrations in surface water, reduce the estimated number of years needed to eliminate fish consumption advisories, reduce the estimated number of achieve sediment conditions protective of fish and wildlife; and reduce PCB loadings to downstream areas.

The threshold criteria evaluation concludes that compliance with all ARARs can be achieved and that no waivers are necessary.

### 3.1.1 Operable Unit 1

Based on consideration listed in Section 3.1, as well as further OU specific information presented in the RI/FS and the BLRA, a level of remediation beyond no action or monitored natural recovery (MNR) is needed to meet threshold criteria for OU 1.

Active remediation in OU 1 is necessary to reduce PCB concentrations in surficial sediment and surface water, reduces the time needed to reach acceptable fish tissue concentrations for humans as well as fish and other wildlife, and will reduce downstream PCB loading into Green Bay to such an extent that active remediation will aid in the recovery of in this OU in an acceptable time. This is further discussed in Section 11 of the ROD for OUs 1 and 2 as well as Sections 5 and 8 of the FS.

### 3.1.2 Operable Unit 2

Based on considerations listed in Section 3.1, above, as well as OU-specific information presented in the RI/FS and the BLRA, MNR is adequate to meet threshold criteria for OU 2.

Concerning OU 2, MNR may take 40 to 70 years to reach safe fish consumption levels for recreational anglers and may take more than 80 years to reach safe ecological levels for carp. However, the recovery times may be overestimated, as these estimates do not consider the removal of Deposit N, which occurred during 1998–1999. Finally, although active remediation may provide a more protective remedy than MNR, risks would only be moderately reduced.

## 3.2 BALANCING CRITERIA

As part of remedy evaluation, the ability of each alternative to meet Balancing Criteria was considered. Balancing Criteria are important components that can define major trade-offs between alternatives and serve as important elements in of project goals that require consideration for successful implementation and long term success of a remediation project. These are discussed in Section 11 of the ROD and Section 9 of the FS.

### 3.2.1 Operable Unit 1

Based on the reduction in residual risk and the adequacy and reliability of controls for the selected remedy, active remediation by dredging with off-site disposal of dewatered sediment is superior to a no action or MNR alternative due to the greater risk reduction and PCB mass removal from OU 1. This remedy also reduces toxicity and mobility of PCB contaminated sediments by eliminating the contaminants from the river thereby reducing the PCB's ability to move in the environment and the amount of contamination present.

Dredging reduces concentrations of PCBs in the sediments' biologically active zone by permanently removing significant contaminated sediment volume and PCB mass from the food web. Furthermore, removal of PCBs will reduce the exposure pathway thus permanently reducing the toxicity associated with the sediments. Disposal of the dewatered sediment into a secure engineered landfill licensed eliminates PCB mobility.

The implementation time for the selected remedy is 6 years at a remedial action level of 1 ppm. This represents the estimated time required for mobilization, operation and demobilization of the remedial work. While the construction of the remedy is underway, access to sediment processing facilities and areas would be restricted to authorized personnel. Work in the river will also be designed with provisions for control of air emissions, noise and light. In summary, the active remediation would not pose significant risk to the nearby communities.

As successfully shown during the Lower Fox River demonstration dredging projects, environmental releases will be minimized during remediation by (1) treating water prior to discharge; (2) controlling storm water run-on and runoff from staging and work areas; and (3) utilizing removal techniques that minimize losses; as well as through (4) the possible use of silt curtains where necessary to reduce the potential downstream transport of PCBs. The active remediation remedy is implementable as well as technically and administratively feasibility. OU 1 costs are estimated to be $ 66.2 million at an action level of 1 ppm.

Based on these considerations, which are in large part from the RI/FS, active remediation is necessary to address balancing criteria for OU 2.

### 3.2.2 Operable Unit 2

The MNR alternative does result in continued degradation of sediments and surface water quality of OU 2, which may last for several decades. Nevertheless, OU 2 will eventually recover as a result of slow natural decreases in concentrations. For MNR, fish consumption advisories and fishing restrictions can provide protection to humans until PCB concentrations in fish are reduced to the point where the fish consumption advisories and fishing restrictions can be relaxed or discontinued. Based on the above analysis of reduction in residual risk and adequacy and reliability of controls, active remediation is only marginally better than MNR and there it would be difficult to consistently achieving any remedial action level.

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered. The MNR alternative is implementable as well as technically and administratively feasible as no active measures would be taken for the PCB-contaminated sediments. Certain institutional controls such as fish consumption advisories will be necessary.

For the majority of OU 2, bedrock underlying contaminated sediments could make complete removal of contaminated sediment and achievement of any RAL impracticable. Active remediation could be more difficult due the large number of locks (many of which are in a state of disrepair) and dams, which limit River access and navigation. The MNR remedy is implementable as well as technically and administratively feasible. Costs for OU 2 are estimated to be $ 9.9 million.

In addition to the above practical considerations, achieving of contaminant concentration (i.e., risk) reductions would be more difficult for dredging areas where bedrock immediately underlies contaminated sediment. Results on projects such as Deposit N or projects with similar conditions (e.g., Manistique River/Harbor) support the idea that achieving reductions in contaminant concentrations would be difficult. Thus, a dredging remedy for this portion of the River would be expected to be less effective and could be more costly for likely only modest risk reduction.

Based on these considerations, which are in large part from the RI/FS, MNR will be adequate to address balancing criteria for OU 2.

## 3.3 REGULATORY AGENCY AND COMMUNITY CRITERIA

State and community acceptance are modifying considerations that are usually taken into formal consideration once public comments have been received. These issues are the same for both OUs 1 and 2. However, at the Lower Fox River and Green Bay Site, the State of Wisconsin has been actively involved in managing the resources of the Lower Fox River since before there was a federal Superfund law. These efforts have led to significant state knowledge and understanding of the River and Bay and of the contamination problems within those areas. As a result of this expertise, WDNR has served as the lead agency responsible for assessing risks and conducting the RI/FS, which forms the basis for the Proposed Plan and ROD. As the lead agency, WDNR has worked closely with EPA to cooperatively develop the ROD. Both WDNR and EPA support the selected remedy identified in the ROD.

Community Acceptance considers whether the local community agrees with EPA's analyses and preferred alternative. Comments received on the Proposed Plan are an important indicator of community acceptance. Community acceptance of the Proposed Plan was evaluated based on comments received at the public meetings and during the public comment period. There were more than 4,800 comments concerning the Proposed Plan. The ROD includes a Responsiveness Summary, Appendix B, that addresses public comments.

Based on the information listed in Sections 3.1 to 3.3, as well as further OU-specific information presented in the RI/FS and the BLRA, a level of remediation beyond no action or MNR is needed to meet CERCLA threshold, balancing, and acceptance criteria for OU 1. However, based on the information in Sections 3.1 to 3.3, as well as OU-specific information presented in the RI/FS and the BLRA, MNR is adequate to meet CERCLA threshold, balancing, and acceptance criteria for OU 2.

## 3.4 OTHER FACTORS

In addition to consideration of the nine CERCLA criteria, discussion of two additional factors in the evaluation of alternatives is worthwhile. This first factor is the potential for the direct release of PCB during active dredging. The second factor is the potential of thin patinas (residual layers) following dredging. In particular, long-term simulations completed using the site-specific chemical transport and bioaccumulation models developed for the RI/FS do not include explicit representations of the potential for direct PCB releases during dredging operations and potential for thin patinas or residual layers to occur immediately following the end of dredging operations. These factors are believed to be of secondary importance. Including or neglecting these factors is not believed to affect the selection of the remedy. Discussion of these two factors follows.

### 3.4.1 Direct Releases PCBs During Active Dredging Operations

Direct releases of PCBs can occur during dredging active operations. Such direct releases of PCBs were not explicitly included in the site-specific chemical transport and bioaccumulation models developed for the RI/FS. This model design factor was based on consideration of the scale of annual PCB mass transport through the River and the ability to control potential releases during dredging. As monitored during the Deposit N and SMU 56/57 demonstration projects, the mass of PCBs released by dredging was roughly two orders of magnitude smaller (less than 1 percent) than the present level of ongoing PCB transport through the Lower Fox River. Assuming full-scale dredging operations were initiated, direct releases of PCBs during dredging (a few kilograms per year) would always be far smaller than natural transport rates (several hundred kilograms per year). Further, as documented by the Sediment Technologies Memorandum (Appendix B of RETEC, 2002b) direct PCB releases during dredging can be minimized by the use of careful controls for during dredging. Note that direct releases of PCBs as a result of propeller wash and bow thrusters by ships traversing the River may be a more significant loss (and uncontrollable) release mechanism. Based on these considerations, direct losses of PCBs during dredging were considered negligible.

### 3.4.2 Post-Dredge Patinas/Residual Layers

Immediately following dredging the end of dredging operations, it is possible that patinas (thin residual layers) of more highly PCB-contaminated sediments may exist at the sediment-water interface. Such patinas were not explicitly included in the site-specific chemical transport and bioaccumulation models developed for the RI/FS. This model design factor was based on consideration of the ability of dredging technologies to achieve low residual PCB concentrations and the rapid rate at which conditions at the sediment-water interface are expected to change following dredging. As monitored following first phase of the SMU 56/57 demonstration project in 1999, PCB concentrations in portions of the dredged area where post-dredging bed elevation meet the target elevation were approximately equal to PCB concentrations initially present at that sediment depth (WDNR, 2000d). This indicates that low residual PCB levels can be achieved by careful control of dredging to ensure sediments are removed with minimum disturbance to a depth required to achieve a desired residual. In addition, dredging alters the sediment transport regime of the dredged area. As a result, conditions near the sediment-water interface can change rapidly following dredging. Post-dredging monitoring of the SMU 56/57 site showed that rapid changes in the sediment-water interface occurred and that conditions a few months following dredging did not resemble conditions immediately following dredging (WDNR, 2002). Based on these considerations, the effect of PCBs potentially present in post-dredge patina layers was considered negligible.

# 4 SUMMARY OF THE SELECTED REMEDY

Taking into account the factors examined as part of the supporting studies, other information in the RI/FS, and public comments, WDNR and EPA recommend the cleanup actions listed in the Proposed Plan (see Table 5 in WDNR and EPA, 2001) for the Lower Fox River and Green Bay. At this time, the Agencies are issuing an ROD for OUs 1 and 2. The selected remedy is consistent with the Proposed Plan for these two OUs.

The are several strong reasons for issuing an ROD for OUs 1 and 2 at this time. These reasons include:

- OUs 1 and 2 represent a smaller portion of the area within the Lower Fox River where remediation is necessary. These two OUs represent approximately 6.5 percent of the PCB mass and 18 percent of the sediment volume in the lower Fox River. Consequently, these two OUs represent a more manageable project than conducting all of the remediation at one time.

- This approach provides for a phased approach to remedial work. Work on upstream areas can start before the downstream areas, which is consistent with EPA policy.

- Planning for OUs 3, 4, and 5 may benefit from knowledge gained on the OUs 1 and 2 project.

- Removal of the PCB-contaminated sediments from OU 1 will result in reduced PCB concentrations in fish tissue, thereby accelerating the reduction in potential future human health and ecological risks in that OU.

- In addition, by addressing the sediments, the remediation will address sources of PCBs upstream of OUs 3 through 5. WDNR and EPA expect to issue a remedy for OUs 3 through 5 in the future.

WDNR and EPA carefully considered more and less stringent cleanup levels (RALs) before selecting the 1 ppm level and believe the 1 ppm RAL is important to achieve the timely reduction of risks to an acceptable level. The selection of the cleanup level is the outcome of a complete and scientifically based risk evaluation. In selection of the 1 ppm RAL, WDNR and EPA considered Remedial Action Objectives (RAOs), model forecasts of the time necessary to achieve risk reduction, risk reduction, the post-remediation Surface-Weighted Average Concentration (SWAC), comparison of the residual SWAC concentration to SQTs for human and ecological receptors, sediment volume and PCB mass to be managed, and cost. The 1 ppm RAL achieves the Agencies' remedial action goals. WDNR and EPA believe this RAL selection is consistent with the 1999 Draft RI/FS. The 1999 Draft RI/FS called for an action level of 0.250 ppm or 0.250 ppm SWAC. The SWAC value resulting from the 1 ppm action level is 0.19 ppm in OU 1.

## TABLE 5 RECOMMENDED REMEDIATION PLAN FROM THE LOWER FOX RIVER AND GREEN BAY PROPOSED PLAN

| Operable Unit | Selected Remedy | PCB Mass Removed (kg) | Contaminated Sediment Volume to Manage (cy) | Estimated Cost (Million $) | Residual SWAC (ppm) |
|---|---|---|---|---|---|
| 1 | Dredge with off-site disposal to 1 ppm PCBs | 1,715 | 784,200 | 66.2 | 0.19 |
| 2 | Monitored natural recovery | 0 | 0 | 9.9 | 0.61 |
| 3 | Dredge with off-site disposal to 1 ppm PCBs | 1,111 | 586,800 | 43.9 | 0.26 |
| 4 | Dredge with off-site disposal to 1 ppm PCBs | 26,433 | 5,879,500 | 173.5 | 0.16 |
| 5 | Monitored natural recovery | 0 | 0 | 39.6 | Not Applicable |

# 5 CONCLUSIONS

Information from many different sources and supporting studies identified the need to implement an active remediation strategy for the Lower Fox River and Green Bay. While no single source of information or study findings in and of itself leads to selection of a remedy, the combination of these findings provides a clear weight of evidence supporting the selection of the remedy described in Sections 3 and 4 for OUs 1 and 2. An approach consistent with this will be followed for OUs 3 through 5. These findings can be categorized in a fashion consistent with the three groupings of the EPA NCP nine CERCLA criteria. The specific findings include:

- **Threshold Criteria**
  - Risks to human health and the ecosystem are unacceptable. Natural recovery has not effectively reduced risks in the 30-plus years timeframe since the manufacturing and recycling of PCB-contaminated carbonless copy paper has ceased. Furthermore, dechlorination in the Lower Fox River appears limited to concentrations that are greater than 30 mg/kg (ppm). This is far above the 1 ppm RAL.
  - WDNR and EPA objectives are to eliminate consumption advisories for recreational anglers within 10 years of completion of remediation and within 30 years for high-intake fish consumers.
  - Comparative modeling shows that active remediation will result in risk reduction more quickly than either the MNR or no action alternatives and will achieve WDNR and EPA risk reduction objectives for certain fish species.
  - Managing to a specific RAL will result in a specific risk-based, surface-weighted action level in any given OU.
  - This work can be completed while complying with ARARs of state and federal rules.
- **Balancing Criteria**
  - There is a large amount of PCBs and contaminated sediment in the Lower Fox River and Green Bay. Much of this sediment is found in the top 100 cm of the sediment bed that can be managed by dredging.
  - The sediment bed in the River is dynamic resulting in resuspension and downstream transport of PCBs in the water column.
  - Dredging technologies can achieve both short-term (e.g., remove to specific elevation or concentration, minimal resuspension of contaminated sediment) as well as long-term goals (e.g., removal of fish consumption advisories) for OU 1.

   - ► An effective post-remediation monitoring program is needed to ensure and measure the effectiveness of any remedial action

- **Regulatory Agency/Community Criteria**

   - ► WDNR and EPA have worked together on the selection of this remedy and both are in agreement with the selection for OUs 1 and 2.

   - ► WDNR and EPA have taken many steps to inform the public of the work being conducted on the Lower Fox River and Green Bay and have used that input to in preparing documents.

   - ► Comments submitted by the public have been considered in the selection of this remedy for OUs 1 and 2. The responses to comments received during the public comment period are included in the Responsiveness Summary that accompanies the ROD for OUs 1 and 2.

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# WHITE PAPER NO. 10 – APPLICABILITY OF THE NRC RECOMMENDATIONS FOR PCB-CONTAMINATED SEDIMENT SITES AND EPA'S 11 CONTAMINATED SEDIMENT MANAGEMENT PRINCIPLES

***Response to Comments by The Fox River Group***

## COMMENTS OF THE FOX RIVER GROUP ON THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES' DRAFT REMEDIAL INVESTIGATION, DRAFT FEASIBILITY STUDY DRAFT BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT AND PROPOSED PLAN

January 2002

***This Document has been Prepared by***

Wisconsin Department of Natural Resources

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# WHITE PAPER NO. 10 – APPLICABILITY OF THE NRC RECOMMENDATIONS FOR PCB-CONTAMINATED SEDIMENT SITES AND EPA'S 11 CONTAMINATED SEDIMENT MANAGEMENT PRINCIPLES

## ABSTRACT

Commenters suggested that the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) does not meet the National Contingency Plan (NCP) criteria and was therefore unlawful. Further, commenters concluded that there had been substantial improvements in the ability of removal technologies and targets, but that none of the *ex-situ* options is completely effective in eliminating risk. And, these risks should be considered when comparing *in-situ* versus *ex-situ* management options. This White Paper demonstrates how the Proposed Plan, and supporting documents, meet the requirements of the NCP, as well as the recommendations of the National Research Council (NRC) and the recently released United States Environmental Protection Agency (EPA) Sediment Management Principles.

## INTRODUCTION

Based on national and growing concern regarding the long-term management of polychlorinated biphenyl (PCB)-contaminated sediments, the National Academy of Sciences (NAS) was mandated by the United States Congress, via the NRC, to address the complexities and risks associated with managing PCB-contaminated sediments. The NRC was tasked with reviewing the availability, effectiveness, cost, and effects of technologies used for the remediation of sediments containing PCBs. The results of their findings were published in a document titled *A Risk Management Strategy for PCB-contaminated Sediments* (NRC, 2001). Based on their review of PCB effects at several sites nationally, the NRC concluded that PCBs in sediment do pose a chronic risk to human health and the environment, and that these risks must be managed. The NRC developed a list of recommendations that captured a need for remedies to be site-specific and risk-based, and that no one remedy (dredging, capping, or monitored natural recovery) is applicable or preferred for all sites.

The recommendations of the NRC were adapted by the EPA in a document titled, *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA, 2002). A copy of that document is attached to this White Paper. EPA used the guiding principles defined by the NRC to develop a set of 11 risk management principles for application at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Resource Conservation and Recovery Act (RCRA) sediment sites. The EPA guidance principles specify use of scientific, risk-based, site-specific remedy decisions using an iterative decision process, as appropriate, which evaluates the short-term and long-term risks of all potential cleanup alternatives. These principles are also consistent with the nine remedy selection criteria defined in the NCP (40 Code of Federal

Regulations [CFR] Part 300.430). Application of these principles does not affect existing statutory and regulatory requirements.

A comparison of the EPA's 11 management principles and the NRC recommendations are presented below. In general, EPA re-articulated the NRC recommendations, but developed more specificity to site cleanups under CERCLA or RCRA. In addition, EPA added a principle not articulated by the NRC that required the agency to maximize the effectiveness of institutional control.

| EPA Risk Management Principles | NRC Recommendations |
|---|---|
| 1. Control sources early. | • Ensure source control. |
| 2. Involve the community early and often. | • Involve community and trustees early. |
| 3. Coordinate with state, local, tribal, and natural resource trustees. | • Societal, cultural, and economic impacts should also be considered. |
| 4. Develop and refine a conceptual site model that considers sediment stability. | • Additional research is needed to assess chemical mixtures and fate/transport processes. |
| 5. Use an iterative approach in a risk-based framework. | • Use a risk-based framework. |
| 6. Evaluate the assumptions and uncertainties associated with site models. | • Select site-specific management decisions. |
| 7. Select site-specific approaches that will achieve risk-based goals. | • PCB exposure may result in adverse human and ecological effects. |
| 8. Ensure that sediment cleanup levels are clearly tied to management goals. | • There is no presumptive remedy.<br>• Management options can reduce but not eliminate PCB exposure. |
| 9. Maximize the effectiveness of institutional controls. | |
| 10. Design remedies to minimize short-term risks while achieving long-term goals. | • Key consideration is management of risks; remedial technology is secondary. |
| 11. Monitor to assess effectiveness. | • Long-term monitoring should be conducted to assess effectiveness. |

The *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a) and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b) are consistent with the findings of the NAS's NRC report entitled *A Risk-Management Strategy for PCB-Contaminated Sediments* (NRC, 2001). The remedy alternatives and action levels developed for the Lower Fox River and Green Bay also considered the 11 guiding principles defined by the EPA. Each of the 11 EPA principles and how they were applied to the Lower Fox River and Green Bay RI/FS process are briefly described below.

## 1. CONTROL SOURCES EARLY

Historically, PCBs were discharged into the Lower Fox River with wastewaters generated from the use and manufacture of carbonless copy paper. Under the Toxic Substances Control Act (TSCA), all manufacture and use of PCBs was banned. Through the efforts of the Wisconsin Department of Natural Resources' (WDNR's) Wisconsin Pollution

Discharge Elimination System (WPDES) program and the discontinued use of PCBs in the production of carbonless copy paper, point source introduction of PCBs into the Lower Fox River has essentially been eliminated.

Surface water quality of the Lower Fox River and Green Bay has been extensively monitored over the last 40 years to determine direct and indirect sources of PCBs to the sediments under investigation. Potential transport pathways such as: outfall discharges, air deposition, groundwater migration, adjacent landfills, sediment resuspension and settling, and urban and agricultural runoff, have been monitored and quantified during previous investigations. These investigations have concluded that today, river sediments are the only significant source of PCBs within the Lower Fox River system. These same investigations and data also have formed the base of knowledge for the PCB fate and transport models constructed and used for this site.

## 2. INVOLVE THE COMMUNITY EARLY AND OFTEN

Meaningful community involvement is a critical component of the site characterization, risk assessment, remedy evaluation, and remedy implementation processes. The PCB contamination of the Lower Fox River has been at the forefront of public discussion and debate for over 20 years. The forum for this discussion has continually evolved. In the early 1980s, following the identification of the Lower Fox River and southern Green Bay as an Area of Concern (AOC) by the International Joint Commission (IJC), a Remedial Action Plan (RAP) public advisory committee was established. Numerous RAP committees were established to address various problems facing the Lower Fox River and Green Bay ecosystems. One such committee, the Science and Technical Advisory Committee (STAC) still meets today and offers input into resolution of the PCB issues. Following from the RAP, the Fox River Coalition (FRC) formed to specifically address the PCB-contaminated sediment issue. The FRC was an assemblage of area municipal, county, state, and local industry leaders that set out to develop a river-wide cleanup plan. The FRC held numerous public meetings and performed some of the initial research into remedial options.

As discussed in the FS (Section 9; RETEC, 2002b), WDNR and EPA have held numerous public/community town meetings, solicited input (door-to-door) from residents, and encouraged active participation during the demonstration sediment remediation projects conducted at Deposit N and Sediment Management Unit (SMU) 56/57 in the Lower Fox River. To further public participation, EPA has twice provided substantial grants to the Clean Water Action Coalition. WDNR regularly publishes the *Fox River Current* newsletter, which is distributed to over 10,000 parties.

To provide greater public input into the development of the final RI/FS and *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c), the agencies released a draft of these documents for public review and comment in February 1999. These draft documents were also subjected to peer reviews conducted by both

EPA and the potentially responsible parties, the Fox River Group. Based on all the public and peer review comments as well as comments received from the National Remedy Review Board, WDNR modified the RI/FS and BLRA and released another draft in October 2001, for additional public comment, along with the Proposed Plan. Most recently, the agencies have reviewed over 4,800 public comments collected during the latest public comment period. The Final RI/FS and BLRA were issued based upon the comments received, as is the Record of Decision.

WDNR also maintains a public website for easy access to data, public documents, meeting minutes, and project updates and resolutions. WDNR is committed to serving the interests of local communities, and facilitating their informed participation, in a balanced and effective manner.

## 3. Coordinate with States, Local Governments, Tribes, and Natural Resource Agencies

At the very start of the RI/FS and BLRA process in 1997, WDNR, EPA, United States Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and the Oneida and Menominee Indian tribes signed a Memorandum of Understanding (MOU). The MOU resulted in the formation of an Intergovernmental Partnership (IGP). Under this IGP, the state as the natural resource trustee coordinates early and often with local governments, tribes, and other Natural Resource Trustees to ensure that all relevant information and viewpoints are being considered when making remedial decisions. In addition, early in the RI/FS and BLRA process, a Biological Technical Assistance Group (BTAG) was formed to assure that the relevant issues and concerns of each regulatory agency and Natural Resource Trustee were addressed in the RI/FS and BLRA process.

## 4. Develop and Refine a Conceptual Site Model that Considers Sediment Stability

The NRC recommends that when models are used to describe relevant PCB exposure pathways that: (1) uncertainty in these models is described, (2) models are calibrated, and (3) models are peer reviewed. The NRC also recommends that the conceptual model includes significant point and non-point sources, release mechanisms, and transport pathways; these pathways are discussed in the RI (RETEC, 2002a).

A comprehensive set of fate and transport models were developed in collaboration with WDNR, EPA, the Fox River Group, which have undergone internal and peer review. These models include the Whole Lower Fox River Model (wLFRM), the Fox River Food Model (FRFood), Green Bay Toxics Model Version E (GBTOXe), and the Green Bay Food Model (GBFood) and have the Lower Fox River and Green Bay fate/transport models are mathematical representations of river hydrodynamics and biota exposure and effect scenarios. These are the models specifically calibrated for the RI/FS and are documented in the *Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin* (MDR) (WDNR and RETEC, 2002). A discussion of the specific models, development history and parameterization is found in Appendix B of the MDR. These models complied with EPA principles by calibrating these models with site-specific data and defining the uncertainty associated with the model assumptions.

Sediment stability was evaluated in the hydrodynamic models via river flooding, scour events, and bed load properties, and calibrated with bathymetric measurements over time. The issue of sediment resuspension is discussed in detail within the MDR for both wLFRM and GBTOXe. Although these models were designed early in the process to guide site investigations and facilitate communication among stakeholders, they have been updated periodically to incorporate new site-specific information. The MDR discusses the PCB fate, transport, and food web models used for the Lower Fox River and Green Bay along with their assumptions, calibrations, and uncertainty.

## 5. USE AN ITERATIVE APPROACH IN A RISK-BASED FRAMEWORK

The risk assessment process implemented for the Lower Fox River and Green Bay followed NRC and EPA recommendations by using a flexible, iterative, and tiered approach, which involved risk characterization that began with a *Screening Level Human Health and Ecological Risk Assessment: Lower Fox River Site, Wisconsin* (SLRA), followed by the BLRA that incorporated a re-evaluation of potential impacts and other site assumptions (RETEC, 1998, 2002c). The BLRA also conformed with NRC recommendations by assuring that: (1) "site-specific" data were evaluated, (2) all available scientific information was incorporated into the assessment, and (3) all affected parties (community, site owners, regulatory agencies) were involved in the review process through the RAP, RAPSTAC, and Fox River Coalition groups. The SLRA was released in 1998 and underwent a public review process by interest groups, local regulators, tribes, and Natural Resource Trustees. The BLRA, released in 2001, was peer reviewed by the AEHS. Comments and concerns were incorporated into the document through several rounds of public involvement, review, and iterations.

## 6. CAREFULLY EVALUATE THE ASSUMPTIONS AND UNCERTAINTIES ASSOCIATED WITH SITE CHARACTERIZATION DATA AND SITE MODELS

The EPA recommends that, during development of site conceptual models and the characterization of site risks, all assumptions and uncertainties be carefully described and evaluated. As a part of the overall program, WDNR and EPA had constructed the Fox River Database (FRDB). The FRDB is a comprehensive collection of all available data sets produced for the river and bay. Over 500,000 data points were included in the FRDB only if they met the strict quality assurance and quality control criteria required under the NCP. The collection and evaluation of these data are documented in the *Data Management Summary Report*, an appendix to the RI. As part of the overall process, EPA had an independent peer review evaluate the FRDB. The BLRA discussed uncertainty associated with the supporting site data, temporal and spatial variability, and toxicity and exposure assumptions made during development of the site models. The uncertainties and assumptions are discussed in the BLRA (RETEC, 2002c) and the MDR (WDNR and RETEC, 2002).

## 7. Select Site-Specific, Project-Specific, and Sediment-Specific Risk Management Approaches that Will Achieve Risk-Based Goals

By WDNR and EPA following strictly the CERCLA process supports the NRC's statement that "there is no presumption of a preferred or default risk-management option that is applicable to all PCB-contaminated-sediments sites" (EPA, 2002). The FS does not select a preferred remedy, instead a range of alternatives, action levels, costs, and their relative risk reduction are presented. Alternatives are compared to each other relative to CERCLA criteria and site-specific Remedial Action Objectives (RAOs). Remedies that potentially reduce the identified site-specific risks and meet the RAOs are evaluated and compared to a natural attenuation (no action) option to identify the most effective management strategy, or combination of strategies for the site.

Final selection of a remedy (and action level) will be a joint WDNR and EPA management decision that will be made in consultation with the IGP. The remedy decision process for the Lower Fox River/Green Bay will involve the evaluation of site-specific data and other project-specific considerations to characterize site risk, community concerns, and long-term benefits. The final remedy for this site will consider the most effective method for reducing PCB exposure and the ensuing effects of such exposure.

## 8. Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals

Although sediment threshold values have been developed and used for identifying areas to be remediated, EPA recommends that other measures be used to ensure that risk reduction goals are met (e.g., reduction in fish tissue concentrations). For the Fox River, elevated concentrations of chemicals of concern (COCs) have been linked to elevated fish tissue levels, fish consumption advisories, bird mortality, and wildlife reproductive health. The weight of evidence clearly demonstrates that the sediment remains the source of these COCs to the river. Therefore, remedial action levels have been proposed based on residual surface-weighted average sediment concentrations (SWAC) that are protective of human and ecological sediment quality thresholds (SQTs). To ensure that the selected remedy for the Lower Fox River is protective of human health (primarily via fish consumption) and the environment, a Model Long-Term Monitoring Plan (RETEC and SAIC, 2002; Appendix C of the FS) is proposed. Measurement endpoints may include: surface sediment concentrations, benthic invertebrate indices, fish tissue concentrations, bird tissue concentrations, and estimates of bird reproduction. Endpoints will be compared to residual risk levels over time and achievement of the project RAOs.

## 9. Maximize the Effectiveness of Institutional Controls and Recognize Their Limitations

Due to elevated PCB levels at the Lower Fox River/Green Bay, WDNR issued consumption advisories for fish and waterfowl in 1976 and 1987, respectively, and Michigan issued fish consumption advisories for Green Bay in 1977. These advisories, which remain in place today for particular species, are intended to limit human exposures until the RAOs are met after implementation and completion of a final remedy.

## 10. Design Remedies to Minimize Short-Term Risks While Achieving Long-Term Protection

In evaluating potential remedies for the Lower Fox River/Green Bay, short-term risks will be minimized to the extent practicable. Risks, such as from resuspended sediment during dredging, will be addressed with the use of appropriate technologies and available control measures. Mitigation methods such as operating hours, routes, and fencing will also be employed to address local short-term implementation issues such as traffic, noise, or recreational use. Admittedly, there will be some instances where short-term risks may inevitably temporarily increase to achieve the long-term remediation goal.

## 11. Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness

A long-term monitoring plan has been prepared as part of the FS to ensure that the selected remedy is adequately mitigating risk and achieving project RAOs. Baseline data, collected before remedial activities begin, will be compared to post-remedy monitoring data. If necessary, the remedy process may be subject to modification to meet the RAOs.

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**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
**WASHINGTON, D.C. 20460**
**Feb. 12, 2002**

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

OSWER Directive 9285.6-08

**MEMORANDUM**

**SUBJECT:** Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites

**FROM:** Marianne Lamont Horinko ***/s/ Marianne Lamont Horinko***
Assistant Administrator

**TO:** Superfund National Policy Managers, Regions 1 - 10
RCRA Senior Policy Advisors, Regions 1 - 10

## I. PURPOSE

This guidance will help EPA site managers make scientifically sound and nationally consistent risk management decisions at contaminated sediment sites. It presents 11 risk management principles that Remedial Project Managers (RPMs), On-Scene Coordinators (OSCs), and RCRA Corrective Action project managers should carefully consider when planning and conducting site investigations, involving the affected parties, and selecting and implementing a response.

This guidance recommends that EPA site managers make risk-based site decisions using an iterative decision process, as appropriate, that evaluates the short-term and long-term risks of all potential cleanup alternatives consistent with the National Oil and Hazardous Substances Pollution Contingency Plan's (NCP's) nine remedy selection criteria (40 CFR Part 300.430). EPA site managers are also encouraged to consider the societal and cultural impacts of existing sediment contamination and of potential remedies through meaningful involvement of affected stakeholders.

This guidance also responds in part to the recommendations contained in the National Research Council (NRC) report discussed below.

## II. Background

on march 26, 2001, the nrc published a report entitled *a risk management strategy for pcb-contaminated sediments*. Although the nrc report focuses primarily on assessment and remediation of PCB-contaminated sediments, much of the information in that report is applicable to other contaminants. Site managers are encouraged to read the NRC report, which may be found at http://www.nrc.edu.

In addition to developing these principles, OSWER, in coordination with other EPA offices (Office of Research and Development, Office of Water, and others) and other federal agencies (Department of Defense/U.S. Army Corps of Engineers, Department of Commerce/National Oceanic and Atmospheric Administration, Department of the Interior/U.S. Fish and Wildlife Service, and others) is developing a separate guidance, *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (Sediment Guidance). The Sediment Guidance will provide more detailed technical guidance on the process that Superfund and RCRA project managers should use to evaluate cleanup alternatives at contaminated sediment sites.

While this directive applies to all contaminants at sediment sites addressed under CERCLA or RCRA, its implementation at particular sites should be tailored to the size and complexity of the site, to the magnitude of site risks, and to the type of action contemplated. These principles can be applied within the framework of EPA's existing statutory and regulatory requirements.

## III. RISK MANAGEMENT PRINCIPLES

### 1. Control Sources Early.

As early in the process as possible, site managers should try to identify all direct and indirect continuing sources of significant contamination to the sediments under investigation. These sources might include discharges from industries or sewage treatment plants, spills, precipitation runoff, erosion of contaminated soil from stream banks or adjacent land, contaminated groundwater and non-aqueous phase liquid contributions, discharges from storm water and combined sewer outfalls, upstream contributions, and air deposition.

Next, site managers should assess which continuing sources can be controlled and by what mechanisms. It may be helpful to prioritize sources according to their relative contributions to site risks. In the identification and assessment process, site managers should solicit assistance from those with relevant information, including regional Water, Air, and PCB Programs (where applicable); state agencies (especially those responsible for setting Total Maximum Daily Loads (TMDLs) and those that issue National Pollutant Discharge Elimination System (NPDES) permits); and all Natural Resource Trustees. Local agencies and stakeholders may also be of assistance in assessing which sources can be controlled.

Site managers should evaluate the potential for future recontamination of sediments when selecting a response action. If a site includes a source that could result in significant recontamination, source control measures will likely be necessary as part of that response action. However, where EPA believes that the source can be controlled, or where sediment remediation will have benefits to human health and/or the environment after considering the risks caused by the ongoing source, it may be appropriate for the Agency to select a response action for the sediments prior to completing all source control actions. This is consistent with principle #5 below, which indicates that it may be necessary to take phased or interim actions (e.g., removal of a hot spot that is highly susceptible to downstream movement or dispersion of contaminants) to prevent or address environmental impacts or to control human exposures, even if source control actions have not been undertaken or completed.

## 2. Involve the Community Early and Often.

Contaminated sediment sites often involve difficult technical and social issues. As such, it is especially important that a project manager ensure early and meaningful community involvement by providing community members with the technical information needed for their informed participation. Meaningful community involvement is a critical component of the site characterization, risk assessment, remedy evaluation, remedy selection, and remedy implementation processes. Community involvement enables EPA to obtain site information that may be important in identifying potential human and ecological exposures, as well as in understanding the societal and cultural impacts of the contamination and of the potential response options. The NRC report (p. 249) "recommends that increased efforts be made to provide the affected parties with the same information that is to be used by the decision-makers and to include, to the extent possible, all affected parties in the entire decision-making process at a contaminated site. In addition, such information should be made available in such a manner that allows adequate time for evaluation and comment on the information by all parties." Through Technical Assistance Grants and other mechanisms, project managers can provide the community with the tools and information necessary for meaningful participation, ensuring their early and continued involvement in the cleanup process.

Although the Agency has the responsibility to make the final cleanup decision at CERCLA and RCRA sites, early and frequent community involvement facilitates acceptance of Agency decisions, even at sites where there may be disagreement among members of the community on the most appropriate remedy.

Site managers and community involvement coordinators should take into consideration the following six practices, which were recently presented in OSWER Directive 9230.0-99 *Early and Meaningful Community Involvement* (October 12, 2001). This directive also includes a list of other useful resources and is available at http://www.epa.gov/superfund/pubs.htm.

(1) Energize the community involvement plan.
(2) Provide early, proactive community support.
(3) Get the community more involved in the risk assessment.

(4) Seek early community input on the scope of the remedial investigation/feasibility study (RI/FS).
(5) Encourage community involvement in identification of future land use.
(6) Do more to involve communities during removals.

**3. Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees.**

Site managers should communicate and coordinate early with states, local governments, tribes, and all Natural Resource Trustees. By doing so, they will help ensure that the most relevant information is considered in designing site studies, and that state, local, tribal, and trustee viewpoints are considered in the remedy selection process. For sites that include waterbodies where TMDLs are being or have been developed, it is especially important to coordinate site investigations and monitoring or modeling studies with the state and with EPA's water program. In addition, sharing information early with all interested parties often leads to quicker and more efficient protection of human health and the environment through a coordinated cleanup approach.

Superfund's statutory mandate is to ensure that response actions will be protective of human health and the environment. EPA recognizes, however, that in addition to EPA's response action(s), restoration activities by the Natural Resource Trustees may be needed. It is important that Superfund site managers and the Trustees coordinate both the EPA investigations of risk and the Trustee investigations of resource injuries in order to most efficiently use federal and state resources and to avoid duplicative efforts.

Additional information on coordinating with Trustees may be found in OSWER Directive 9200.4-22A *CERCLA Coordination with Natural Resource Trustee*s (July 1997), in the 1992 ECO Update *The Role of Natural Resource Trustees in the Superfund Process* http://www.epa.gov/superfund/programs/risk/tooleco.htm), and in the 1999 OSWER Directive 9285.7-28 P *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (also available at the above web site). Additional information on coordinating with states and tribes can be found in OSWER Directive 9375.3-03P *The Plan to Enhance the Role of States and Tribes in the Superfund Program* (http://www.epa.gov/superfund/states/strole/index.htm).

**4. Develop and Refine a Conceptual Site Model that Considers Sediment Stability.**

A conceptual site model should identify all known and suspected sources of contamination, the types of contaminants and affected media, existing and potential exposure pathways, and the known or potential human and ecological receptors that may be threatened. This information is frequently summarized in pictorial or graphical form, backed up by site-specific data. The conceptual site model should be prepared early and used to guide site investigations and decision-making. However, it should be updated periodically whenever new information becomes available, and EPA's understanding of the site problems increases. In addition, it frequently can serve as the centerpiece for communication among all stakeholders.

A conceptual site model is especially important at sediment sites because the interrelationship of soil, surface and groundwater, sediment, and ecological and human receptors is often complex. In addition, sediments may be subject to erosion or transport by natural or man-made disturbances such as floods or engineering changes in a waterway. Because sediments may experience temporal, physical, and chemical changes, it is especially important to understand what contaminants are currently available to humans and wildlife, and whether this is likely to change in the future under various scenarios. The risk assessor and project manager, as well as other members of the site team, should communicate early and often to ensure that they share a common understanding of the site and the basis for the present and future risks. The May 1998 EPA *Guidelines for Ecological Risk Assessment* (Federal Register 63(93) 26846-26924, http://www.epa.gov/superfund/programs/risk/tooleco.htm), the 1997 Superfund Guidance *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 540-R-97-006, also available at the above web site), and the 1989 *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Part A* (EPA 540-1-89-002, http://www.epa.gov/superfund/programs/risk/ragsa) provide guidance on developing conceptual site models.

## 5. Use an Iterative Approach in a Risk-Based Framework.

The NRC report (p. 52) recommends the use of a risk-based framework based on the one developed by the Presidential/Congressional Commission on Risk Assessment and Risk Management (PCCRARM, 1997, *Framework for Environmental Health Risk Management*, Vol. 1, as cited by NRC 2001). However, as recognized by the NRC (p. 60): “The framework is intended to supplement, not supplant, the CERCLA remedial process mandated by law for Superfund sites.”

Although there is no universally accepted, well-defined risk-based framework or strategy for remedy evaluation at sediment sites, there is wide-spread agreement that risk assessment should play a critical role in evaluating options for sediment remediation. The Superfund program uses a flexible, risk-based framework as part of the CERCLA and NCP process to adequately characterize ecological and human health site risks. The guidances used by the RCRA Corrective Action program (http://www.epa.gov/correctiveaction/resource/guidance) also recommend a flexible risk-based approach to selecting response actions appropriate for the site.

EPA encourages the use of an iterative approach, especially at complex contaminated sediment sites. As used here, an iterative approach is defined broadly to include approaches which incorporate testing of hypotheses and conclusions and foster re-evaluation of site assumptions as new information is gathered. For example, an iterative approach might include pilot testing to determine the effectiveness of various remedial technologies at a site. As noted in the NRC report (p. 66): "Each iteration might provide additional certainty and information to support further risk-management decisions, or it might require a course correction."

An iterative approach may also incorporate the use of phased, early, or interim actions. At complex sediment sites, site managers should consider the benefits of phasing the remediation. At some sites, an early action may be needed to quickly reduce risks or to control the ongoing spread of contamination. In some cases, it may be appropriate to take an interim action to control a source, or remove or cap a hot spot, followed by a period of monitoring in order to evaluate the effectiveness of these interim actions before addressing less contaminated areas.

The NRC report makes an important point when it notes (p. 256): "The committee cautions that the use of the framework or other risk-management approach should not be used to delay a decision at a site if sufficient information is available to make an informed decision. Particularly in situations in which there are immediate risks to human health or the ecosystem, waiting until more information is gathered might result in more harm than making a preliminary decision in the absence of a complete set of information. The committee emphasizes that a 'wait-and-see' or 'do-nothing' approach might result in additional or different risks at a site."

**6. Carefully Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models.**

The uncertainties and limitations of site characterization data, and qualitative or quantitative models (e.g., hydrodynamic, sediment stability, contaminant fate and transport, or food-chain models) used to extrapolate site data to future conditions should be carefully evaluated and described. Due to the complex nature of many large sediment sites, a quantitative model is often used to help estimate and understand the current and future risks at the site and to predict the efficacy of various remedial alternatives. The amount of site-specific data required and the complexity of models used to support site decisions should depend on the complexity of the site and the significance of the decision (e.g., level of risk, response cost, community interest). All new models and the calibration of models at large or complex sites should be peer-reviewed consistent with the Agency's peer review process as described in its Peer Review Handbook (EPA 100-B-00-001, http://www.epa.gov/ORD/spc/2peerrev.htm).

Site managers should clearly describe the basis for all models used and their uncertainties when using the predicted results to make a site decision. As recognized by the NRC report (p. 65), however, "Management decisions must be made, even when information is imperfect. There are uncertainties associated with every decision that need to be weighed, evaluated, and communicated to affected parties. Imperfect knowledge must not become an excuse for not making a decision."

## 7. Select Site-specific, Project-specific, and Sediment-specific Risk Management Approaches that will Achieve Risk-based Goals.

EPA's policy has been and continues to be that there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk. This is consistent with the NRC report's statement (p. 243) that "There is no presumption of a preferred or default risk-management option that is applicable to all PCB-contaminated-sediment sites." At Superfund sites, for example, the most appropriate remedy should be chosen after considering site-specific data and the NCP's nine remedy selection criteria. All remedies that may potentially meet the removal or remedial action objectives (e.g., dredging or excavation, in-situ capping, in-situ treatment, monitored natural recovery) should be evaluated prior to selecting the remedy. This evaluation should be conducted on a comparable basis, considering all components of the remedies, the temporal and spatial aspects of the sites, and the overall risk reduction potentially achieved under each option.

At many sites, a combination of options will be the most effective way to manage the risk. For example, at some sites, the most appropriate remedy may be to dredge high concentrations of persistent and bioaccumulative contaminants such as PCBs or DDT, to cap areas where dredging is not practicable or cost-effective, and then to allow natural recovery processes to achieve further recovery in net depositional areas that are less contaminated.

## 8. Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals.

Sediment cleanup levels have often been used as surrogates for actual remediation goals (e.g., fish tissue concentrations or other measurable indicators of exposure relating to levels of acceptable risk). While it is generally more practical to use measures such as contaminant concentrations in sediment to identify areas to be remediated, other measures should be used to ensure that human health and/or ecological risk reduction goals are being met. Such measures may include direct measurements of indigenous fish tissue concentrations, estimates of wildlife reproduction, benthic macroinvertebrate indices, or other "effects endpoints" as identified in the baseline risk assessment.

As noted in the NRC report (p. 123), "The use of measured concentrations of PCBs in fish is suggested as the most relevant means of measuring exposures of receptors to PCBs in contaminated sediments." For other contaminants, other measures may be more appropriate. For many sites, achieving remediation goals, especially for bioaccumulative contaminants in biota, may take many years. Site monitoring data and new scientific information should be considered in future reviews of the site (e.g., the Superfund five-year review) to ensure that the remedy remains protective of human health and the environment.

## 9. Maximize the Effectiveness of Institutional Controls and Recognize their Limitations.

Institutional controls, such as fish consumption advisories and waterway use restrictions, are often used as a component of remedial decisions at sediment sites to limit human exposures and to prevent further spreading of contamination until remedial action objectives are met. While these controls can be an important component of a sediment remedy, site managers should recognize that they may not be very effective in eliminating or significantly reducing all exposures. If fish consumption advisories are relied upon to limit human exposures, it is very important to have public education programs in place. For other types of institutional controls, other types of compliance assistance programs may also be needed (e.g., state/local government coordination). Site managers should also recognize that institutional controls seldom limit ecological exposures. If monitoring data or other site information indicates that institutional controls are not effective, additional actions may be necessary.

## 10. Design Remedies to Minimize Short-term Risks while Achieving Long-term Protection.

The NRC report notes (p. 53) that: "Any decision regarding the specific choice of a risk management strategy for a contaminated sediment site must be based on careful consideration of the advantages and disadvantages of available options and a balancing of the various risks, costs, and benefits associated with each option." Sediment cleanups should be designed to minimize short-term impacts to the extent practicable, even though some increases in short-term risk may be necessary in order to achieve a long-lasting solution that is protective. For example, the long-term benefits of removing or capping sediments containing persistent and bioaccumulative contaminants often outweigh the additional short-term impacts on the already-affected biota.

In addition to considering the impacts of each alternative on human health and ecological risks, the short-term and long-term impacts of each alternative on societal and cultural practices should be identified and considered, as appropriate. For example, these impacts might include effects on recreational uses of the waterbody, road traffic, noise and air pollution, commercial fishing, or disruption of way of life for tribes. At some sites, a comparative analysis of impacts such as these may be useful in order to fully assess and balance the tradeoffs associated with each alternative.

## 11. Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness.

A physical, chemical, and/or biological monitoring program should be established for sediment sites in order to determine if short-term and long-term health and ecological risks are being adequately mitigated at the site and to evaluate how well all remedial action objectives are being met. Monitoring should normally be conducted during remedy implementation and as long as necessary thereafter to ensure that all sediment risks have been adequately managed.

Baseline data needed for interpretation of the monitoring data should be collected during the remedial investigation.

Depending on the risk management approach selected, monitoring should be conducted during implementation in order to determine whether the action meets design requirements and sediment cleanup levels, and to assess the nature and extent of any short-term impacts of remedy implementation. This information can also be used to modify construction activities to assure that remediation is proceeding in a safe and effective manner. Long-term monitoring of indicators such as contaminant concentration reductions in fish tissue should be designed to determine the success of a remedy in meeting broader remedial action objectives. Monitoring is generally needed to verify the continued long-term effectiveness of any remedy in protecting human health and the environment and, at some sites, to verify the continuing performance and structural integrity of barriers to contaminant transport.

## IV. IMPLEMENTATION

EPA RPMs, OSCs, and RCRA Corrective Action project managers should immediately begin to use this guidance at all sites where the risks from contaminated sediment are being investigated. EPA expects that Federal facility responses conducted under CERCLA or RCRA will also be consistent with this directive. This consultation process does not apply to Time-Critical or emergency removal actions or to sites with only sediment-like materials in wastewater lagoons, tanks, storage or containment facilities, or drainage ditches.

### Consultation Process for CERCLA Sites

To help ensure that Regional site managers appropriately consider these principles *before* site-specific risk management decisions are made, this directive establishes a two-tiered consultation procedure that will apply to most contaminated sediment sites. The consultation process applies to all proposed or listed NPL sites where EPA will sign or concur on the ROD, all Non-Time-Critical removal actions where EPA will sign or concur on the Action Memorandum, and all "NPL-equivalent" sites where there is or will be an EPA-enforceable agreement in place.

<u>Tier 1 Process</u>

Where the sediment action(s) for the entire site will address more than 10,000 cubic yards or five acres of contaminated sediment, Superfund RPMs and OSCs should consult with their appropriate Office of Emergency and Remedial Response (OERR) Regional Coordinator at least 30 days before issuing for public comment a Proposed Plan for a remedial action or an Engineering Evaluation/Cost Analysis (EE/CA) for a Non-Time-Critical removal action.

This consultation entails the submission of the draft proposed plan or draft EE/CA, a written discussion of how the above 11 principles were considered, and basic site information that will assist OERR in tracking significant sediment sites. If the project manager has not received a response from OERR within two weeks, he or she may assume no further information is needed at this time. EPA believes that this process will help promote nationally consistent approaches to evaluate, select and implement protective, scientifically sound, and cost-effective remedies.

Tier 2 Process

This directive also establishes a new technical advisory group (Contaminated Sediments Technical Advisory Group–CSTAG) that will monitor the progress of and provide advice regarding a small number of large, complex, or controversial contaminated sediment Superfund sites. The group will be comprised of ten Regional staff and approximately five staff from OSWER, OW, and ORD. For most sites, the group will meet with the site manager and the site team several times throughout the site investigation, response selection, and action implementation processes. For new NPL sites, the group will normally meet within one year after proposed listing. It is anticipated that for most sites, the group will meet annually until the ROD is signed and thereafter as needed until all remedial action objectives have been met. The specific areas of assistance or specific documents to be reviewed will be decided by the group on a case-by-case basis in consultation with the site team. For selected sites with an on-going RI/FS or EE/CA, the group will be briefed by the site manager some time in 2002 or 2003. Reviews at sites with remedies also subject to National Remedy Review Board (NRRB) review will be coordinated with the NRRB in order to eliminate the need for a separate sediment group review at this stage in the process.

**Consultation Process for RCRA Corrective Action Facilities**

Generally, for EPA-lead RCRA Corrective Action facilities where a sediment response action is planned, a two-tiered consultation process will also be used. Where the sediment action(s) for the entire site will address more than 10,000 cubic yards or five acres of contaminated sediment, project managers should consult with the Office of Solid Waste's Corrective Action Branch at least 30 days before issuing a proposed action for public comment. This consultation entails the submission of a written discussion of how the above 11 principles were considered, and basic site information that will assist OSW in tracking significant sediment sites.

If the project manager has not received a response from OSW within two weeks, he or she may assume no further information is needed. States are also encouraged to follow these procedures. For particularly large, complex, or controversial sites, OSW will likely call on the technical advisory group discussed above.

EPA also recommends that both state and EPA project managers working on sediment contamination associated with Corrective Action facilities consult with their colleagues in both RCRA and Superfund to promote consistent and effective cleanups. EPA believes this consultation would be particularly important for the larger-scale sediment cleanups mentioned above.

EPA may update this guidance as more information becomes available on topics such as: the effectiveness of various sediment response alternatives, new methods to evaluate risks, or new methods for characterizing sediment contamination. For additional information on this guidance, please contact the OERR Sediments Team Leader (Stephen Ells at 703 603-8822) or the OSW Corrective Action Programs Branch Chief (Tricia Buzzell at 703 308-8632).

NOTICE: This document provides guidance to EPA Regions concerning how the Agency intends to exercise its discretion in implementing one aspect of the CERCLA and RCRA remedy selection process. This guidance is designed to implement national policy on these issues. Some of the statutory provisions described in this document contain legally binding requirements. However, this document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus it cannot impose legally binding requirements on EPA, states, or the regulated community, and may not apply to a particular situation based upon the circumstances. Any decisions regarding a particular situation will be made based on the statutes and regulations, and EPA decision-makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Interested parties are free to raise questions and objections about the substance of this guidance and the appropriateness of the application of this guidance to a particular situation, and the Agency welcomes public input on this document at any time. EPA may change this guidance in the future.

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# White Paper No. 11 – Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River

## Response to Public Comments Received

*This Document has been Prepared by*

Wisconsin Department of Natural Resources

**December 2002**

# WHITE PAPER NO. 11 –
# COMPARISON OF SQTS, RALS, RAOS, AND SWACS FOR THE LOWER FOX RIVER

## ABSTRACT

Commenters expressed confusion over sediment quality thresholds (SQTs), remedial action levels (RALs), remedial action objectives (RAOs), and surface-weighted average concentrations (SWACs). Further, commenters expressed concern that the action levels were not risk based. The purpose of this White Paper is to respond to the comments received, to clarify these terms, and show the relationship between them.

This White Paper summarizes the nomenclature that was used throughout the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* and *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (RI/FS) (RETEC, 2002a, 2002b) process to describe sediment concentrations of contaminants of concern (COCs). The discussion includes descriptions of SQTs, RALs, RAOs, and SWACs. The relationship between these concentrations of total polychlorinated biphenyls (PCBs) is presented on Figure 1 and in Table 1. WDNR and EPA in the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001) selected an RAL of 1 ppm for Operable Units (OUs) 1, 3, and 4, and monitored natural recovery (MNR) for OUs 2 and 5. As indicated on Figure 1, assuming an agency-selected RAL of 1 part per million (ppm), the resultant SWACs for each River reach are well below the RAL. Future projections described in the FS indicate that SQTs for recreational anglers will be met in 10 years, SQTs for high-intake fish consumers will be met in 30 years, and SQTs for wildlife will be met in 30 years.

## INTRODUCTION

The overall objective of the RI/FS was to evaluate corrective actions that may be applied to contaminated sediment within the Lower Fox River and Green Bay. The remedial actions were evaluated based on knowledge of the current potential risk to human health and wildlife posed by COCs, and the likelihood of risk reduction resulting from remedial action. This approach is consistent with that recommended by the National Research Council's report to Congress (NRC, 2001).

PCBs were identified as the principal contaminant causing or potentially causing risk to human health and the environment. In order to translate risks to human health and the environment into a cleanup goal, it became necessary to associate risks with sediment concentrations of PCBs. Three separate but related risk and remedial action numbers were generated in the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c) and the FS. These are as follows:

- **Sediment Quality Thresholds** were developed that linked single-point concentrations of PCBs to specific risks to human health and the environment.

- **Surface-Weighted Average Concentrations** related the single point risk estimate in the SQT to the entire area of the OU (e.g., Little Lake Butte des Morts [OU 1], De Pere dam to Green Bay [OU 4]).

- **Remedial Action Level** is the engineering design level around which the removal or containment alternative is structured. The RAL is selected so that when the cleanup is achieved, the SWAC is also achieved.

The relationship between these three are shown on Figure 1 and are discussed in more detail below.

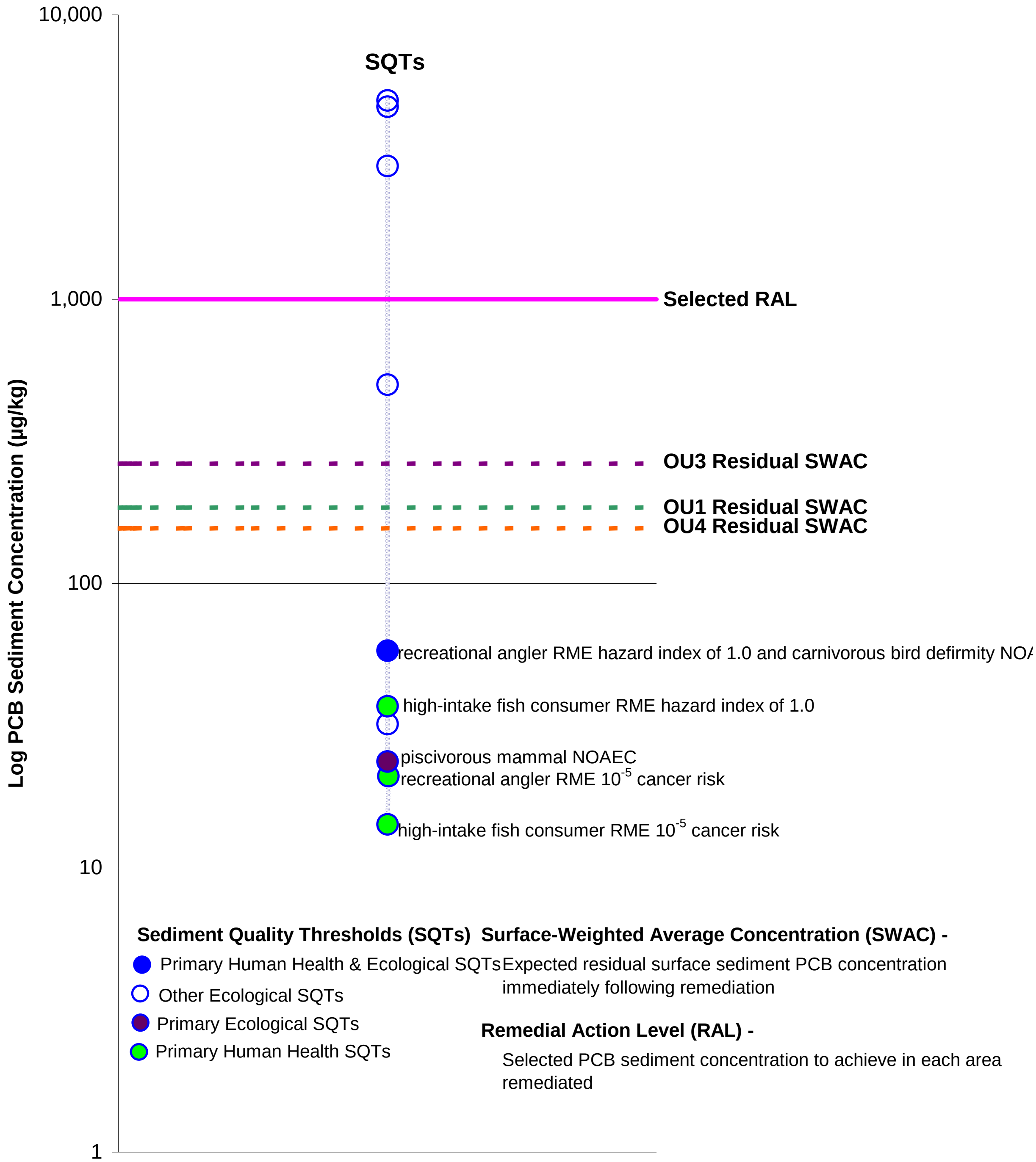
## SEDIMENT QUALITY THRESHOLDS

To facilitate the selection of a remedy that would result in decreased risks, it was necessary to establish a link between levels of PCBs toxic to human and ecological receptors and the principal source of those PCBs, the Lower Fox River and Green Bay sediment. SQTs are estimated threshold concentrations of PCBs in sediment that below which risks should not occur.

SQTs should be considered as point estimates (i.e., they are calculated for a specific sediment location, pathway, and receptor). SQT thresholds are site-specific, and are developed in Section 7 of the BLRA for each pathway and receptor identified as important by the resource agencies for the Lower Fox River and Green Bay (e.g., sport fishing consumption, bald eagles). These risk-based sediment thresholds were determined based on cancer and noncancer risks to humans, and no and low observed adverse effect concentrations for each ecological receptor. Other inputs included receptor-specific (e.g., fish, bird, and mammal) dietary preferences, fish lipid concentrations, and total organic carbon sediment concentrations. These inputs were also specific to each OU of the River.

The SQTs themselves are not cleanup criteria, but are a good approximation of protective sediment thresholds and were considered to be “working values” from which RALs were selected.

## Figure 1 Target PCB Concentrations in Sediment Lower Fox River and Green Bay



## TABLE 1 RELATIONSHIP OF TOTAL PCB SQTS TO RALS, SWACS, AND RISK

| Sediment Total PCB Concentration (µg/kg) | Sediment Quality Threshold (SQT) (µg/kg) | Whole Fish Threshold Concentration (µg/kg) | Fish | Risk Level | Receptor | Sediment Remedial Action Level (RAL) (µg/kg) | River Reach and Residual SWACs | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | OU 1 | OU 2 | OU 3 | OU 4 |
| 14 | 14 | 71 | walleye | RME $10^{-5}$ cancer risk level | high-intake fish consumer | — | — | — | — | — |
| 21 | 21 | 106 | walleye | RME $10^{-5}$ cancer risk level | recreational angler | — | — | — | — | — |
| 24 | 24 | 50 | carp | piscivorous mammal NOAEC | mink | — | — | — | — | — |
| 32 | 32 | — | — [1] | TEL | sediment invertebrate | — | — | — | — | — |
| 37 | 37 | 181 | walleye | RME hazard index of 1.0 | high-intake fish consumer | — | — | — | — | — |
| 58 | 58 | 288 | walleye | RME hazard index of 1.0 | recreational angler | — | — | — | — | — |
| | | 121 | carp | carnivorous bird deformity NOAEC | bald eagle | — | — | — | — | — |
| 125 | — | — | — | — | — | 125 | 51 | 50 | 54 | 54 |
| 250 | — | — | — | — | — | 250 | 66 | 55 | 80 | 67 |
| 500 | 500 | 408 | gizzard shad | piscivorous bird deformity NOAEC | Forster's tern | 500 | 103 | 61 | 147 | 93 |
| 1,000 | — | — | — | — | — | 1,000 | 185 | 68 | 264 | 156 |
| 2,940 | 2,940 | 2,399 | gizzard shad | piscivorous bird hatching success NOAEC | Forster's tern | — | — | — | — | — |
| 4,753 | 4,753 | 3,879 | gizzard shad | piscivorous bird hatching success LOAEC | Forster's tern | — | — | — | — | — |
| 5,000 | 5,003 | 4,083 | gizzard shad | piscivorous bird deformity LOAEC | Forster's tern | 5,000 | 727 | 95 | 732 | 887 |
| 10,000 | — | — | — | — | — | 10,000 | 1,067 | 126 | 1,038 | 1,946 |
| No Action | — | — | — | — | — | No Action | 4,165 | 607 | 2,306 | 3,110 |

**Notes:**
1 The media here is not a fish, but rather sediment.
Selected RAL (µg/kg). Note that for OU 2, MNR was the selected action
"—" - Information not available.

## SURFACE-WEIGHTED AVERAGE CONCENTRATION

The SWAC is the concentration of PCBs in sediments calculated as an average over the entire surface area of an OU. Since it is used to evaluate risks, the SWAC is calculated using the surface sediment concentrations in the OU, defined as the top 10 cm of sediment. SWACs were calculated for baseline risk and for post-remedial actions based on a series of evaluated RALs (e.g., 0.125, 0.25, 0.5, 1 ppm, etc.) in Section 5 of the FS.

Thus, specific cleanup goals, or RALs, can be evaluated relative to post-remedial risks.

## REMEDIAL ACTION LEVELS

RALs are potential PCB remediation cleanup criteria for sediment that were evaluated in the FS and define the size of the dredge prism requiring removal. The RALs selected for evaluation (e.g., 0.125, 0.25, 0.5, and 1 ppm PCBs) were based on several considerations:

- Action levels should bracket the human health and ecological SQT values;
- The lowest action level should be a concentration where the residual SWAC is protective of approximately 90 percent of human and ecological receptors;
- The highest action level should be a concentration where the residual SWAC is protective of approximately 10 percent of human/ecological receptors;
- Action levels should be implementable based on the precedent set on other site sediment remediation projects; and
- Action levels should bracket a commonly implemented action level of 1 ppm PCBs.

## INTEGRATION OF THE RAL, SQT, AND SWAC

The relationship of the selected RAL, SQT, and SWAC is shown on Figure 1. The proposed RAL for the Lower Fox River has been set at 1 ppm total PCBs and is shown on the figure as a solid bar. The individual SQTs for human health and ecological receptors are shown on the figure to be above, and below, the selected RAL. The important consideration from a risk management consideration is the individual reach SWAC. In each case, the resultant SWAC is less than the RAL: for Little Lake Butte des Morts (OU 1), the resultant SWAC is 185 ppb; for De Pere to Green Bay (OU 4), it is 156 ppb. WDNR and EPA made a risk management decision and selected the proposed remedy based in part upon a consideration of allowing some natural attenuation to occur post-remediation that would ultimately achieve the final desired SQT.

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# WHITE PAPER NO. 12 – HUDSON RIVER RECORD OF DECISION
# PCB CARCINOGENICITY WHITE PAPER

***Response to a Review of***

## DRAFT BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT
## FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN
## REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

October 2001

***This Document has been Prepared by***
United States Environmental Protection Agency

**December 2002**

# WHITE PAPER NO. 12 – HUDSON RIVER RECORD OF DECISION PCB CARCINOGENICITY WHITE PAPER

The white paper contained in this attachment was prepared as part of the Record of Decision for the Hudson River in New York. The topic of focus – PCBs as carcinogens – has relevance to the Lower Fox River and Green Bay site and the response to comments received on the Baseline Human Health and Ecological Risk Assessment and are defended by WDNR and EPA.

# PCB CARCINOGENICITY (ID362702)

## ABSTRACT

EPA classifies PCBs as probable human carcinogens based on data showing that PCBs cause cancer in animals and inadequate but suggestive evidence that PCBs cause cancer in humans. EPA's guidelines for classifying the carcinogenicity of chemicals are consistent with the approaches used by other national and international agencies. Moreover, EPA's Weight of Evidence classification of PCBs as probable human carcinogens has been externally peer reviewed and is equivalent to the classifications of the National Toxicology Program, the National Institute of Occupational Safety and Health, and the International Agency for Research on Cancer, part of the World Health Organization.

In the Human Health Risk Assessment for the Hudson River PCBs Site, EPA used the current externally peer-reviewed toxicity values for PCB carcinogenicity (i.e., cancer slope factors) contained in the Integrated Risk Information System, which is the Agency's consensus database of toxicity information. In the Human Health Risk Assessment, EPA summarized recent human epidemiological studies published since the 1996 PCB Cancer Reassessment. Based on a review of these newer studies, EPA determined that no change was necessary to EPA's classification of PCBs as probable human carcinogens. In the Human Health Risk Assessment, cancer risks from dioxin-like PCBs were calculated using current Toxicity Equivalency Factors developed by the World Health Organization. EPA submitted the Human Health Risk Assessment for external peer review. The peer reviewers agreed with the toxicity values EPA used in the Human Health Risk Assessment.

## INTRODUCTION

The purpose of this paper is to provide an overview of EPA's process for evaluating the carcinogenicity of a chemical, development of cancer slope factors for PCBs, and the application of this toxicity information in the Human Health Risk Assessment for the Hudson River PCBs Site.

This paper is divided into four parts. The first part describes the history and development of the Agency's guidelines for carcinogenicity (USEPA, 1976, 1980, 1983a,b, 1984, 1986, 1994, 1996a, 1999a). Specific issues addressed in the guidelines include EPA's PCB Weight of Evidence classification, procedures for evaluating human epidemiological evidence and animal toxicity studies, and the use of this information in classifying the carcinogenicity of a chemical. The second part of this paper describes the Agency's evaluation of the carcinogenicity of PCBs. It summarizes the important human epidemiological and animal studies evaluated during the 1996 Cancer Reassessment for PCB carcinogenicity (USEPA, 1996b), presents some of the new information on the cancer toxicity of PCBs evaluated by EPA since 1996, and presents the current cancer slope factors in the Integrated Risk Information System (IRIS), the Agency's consensus database of toxicity information (USEPA, 1999b).

The third part provides a list of published papers describing some of the PCB toxicity research conducted by EPA scientists in the past 5 years, including studies of the mechanisms by which PCBs cause cancer and other adverse health effects.

The fourth part of this paper addresses the use of PCB cancer toxicity information in the Human Health Risk Assessment (HHRA) for the Hudson River PCBs Site (USEPA, 2000a–d). Specifically, this section discusses the use of cancer toxicity information (e.g., cancer slope factors) in IRIS and the toxic equivalency factors (TEFs) for dioxin-like PCBs. This section also describes the Agency's rationale for not using blood PCB levels in workers to evaluate cancer risks for people who eat PCB-contaminated fish from the Hudson River.

## DEVELOPMENT OF EPA CARCINOGEN GUIDELINES

EPA's Carcinogen Guidelines (USEPA, 1976, 1983a,b, 1984, 1986, 1994, 1996a, 1999a) were used in determining the carcinogenicity of PCBs. These guidelines provide EPA's general framework for evaluating the cancer toxicity data (human and animal) for determining the Weight of Evidence classifications and cancer slope factors of chemicals. The Carcinogen Guidelines were developed after an evaluation of the procedures used by the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO) and the National Toxicology Program (NTP), which is part of the National Institutes of Health. In 1976, EPA issued interim procedures and guidelines for health risks and economic impact assessments of suspected carcinogens (USEPA, 1976). In 1979, the Interagency Regulatory Liaison Group held a meeting regarding carcinogens and methods for evaluating the technical adequacy of animal toxicity studies (IRLG, 1979).

In 1982, IARC issued a monograph on the evaluation of the carcinogenic risk of chemicals to humans (IARC, 1982). In 1984, NTP's Ad Hoc Panel on Chemical Carcinogenesis Testing and Evaluation issued a report regarding selection of dose levels for long-term animal studies (NTP, 1984).

In 1984, EPA began its work on the Guidelines for Carcinogen Risk Assessment (EPA, 1984). Draft guidelines were developed by a workgroup composed of expert scientists from throughout the Agency. The draft was externally peer reviewed by expert scientists in the field of carcinogenesis and related scientific disciplines, from universities, environmental groups, industry, labor, and other governmental agencies. The guidelines were then proposed for public comment in the Federal Register (EPA, 1984).

In 1986, EPA issued the Guidelines for Carcinogen Risk Assessment (September 24, 1986), which are the product of a 2-year Agency-wide effort, which has included many scientists from the larger scientific community (USEPA, 1986). These guidelines incorporated comments and responses to external peer review comments and comments from the Agency's Science Advisory Board and were finalized and published in the Federal Register (USEPA, 1986). The guidelines incorporate information from the previous documents and also information and procedures used by NTP and IARC (e.g., the Weight of Evidence classification is based on the IARC approach). The 1986 Guidelines incorporated principles of the science for chemical carcinogens issued by the Office of Science and Technology Policy in 1985 (OSTP, 1985).

On April 23, 1996, the Proposed Guidelines for Carcinogen Risk Assessment were published in the Federal Register (USEPA, 1996a) for a 120-day public review and comment period. The Proposed Carcinogen Guidelines are a revision of EPA's 1986 Guidelines for Carcinogen Risk Assessment (USEPA, 1986) and, when final, will replace the 1986 cancer guidelines (USEPA, 1996a). The full text of the Federal Register notice is available on the web at www.epa.gov/ncea/.

Changes since the 1986 Carcinogen Guidelines (USEPA, 1986) are summarized in the 1996 Proposed Carcinogen Guidelines (USEPA, 1996a), as follows:

> "Since the publication of the 1986 cancer guidelines, there is a better understanding of the variety of ways in which carcinogens can operate. Today, many laboratories are moving toward adding new test protocols in their programs directed at mode of action questions. Therefore, the Proposed Guidelines provide an analytical framework that allows for the incorporation of all relevant biological information, recognize a variety of situations regarding cancer hazard, and are flexible enough to allow for consideration of future scientific advances."

In 1999, EPA proposed revised Carcinogen Guidelines (USEPA, 1999a) in response to comments by the EPA Science Advisory Board. The approaches outlined in the proposed revised guidelines are consistent with the 1996 Cancer Reassessment for PCBs (USEPA, 1996a). The 1999 proposed guidelines were developed to address issues regarding children's risk from exposure to carcinogens. On November 21, 2001, EPA published an announcement in the Federal Register soliciting additional scientific information and comments on the draft revised Carcinogen Guidelines that could assist EPA in completing the final Guidelines (USEPA, 2001). This Federal Register notice also stated that, until final Guidelines are issued, the July 1999 draft revised Guidelines will serve as EPA's interim guidance to EPA risk assessors preparing cancer risk assessments.

As outlined above, the carcinogenicity guidelines were developed within the Agency, published in the Federal Register for comment, and externally peer-reviewed. EPA responded to comments on the proposed guidelines and made changes based on a review of the comments submitted by these groups and individuals. The guidelines were also submitted for review to EPA's Science Advisory Board, an external scientific review panel.

## EPA'S EVALUATION OF PCB CARCINOGENICITY

EPA classified PCBs as probable human carcinogens in 1988 (USEPA, 1988) and reaffirmed this classification in 1996 (USEPA, 1996b). EPA's classification is based on a weight of the evidence. The available classifications for chemicals are: (a) carcinogenic to humans, (b) probably carcinogenic to humans, (c) possibly carcinogenic to humans, (d) not classifiable as to human carcinogenicity, and (e) evidence of non-carcinogenicity to humans. The EPA classification of PCBs as probable human carcinogens is equivalent to the NTP, NIOSH, and IARC classifications for PCBs (NTP, 1981, 2000; NIOSH, 1977; IARC, 1978, 1987).

Following the 1988 evaluation of the carcinogenicity of PCBs, EPA conducted a reassessment of the carcinogenicity of PCBs in 1996 (USEPA, 1996b, see also www.epa.gov/ncea). In developing EPA's cancer reassessment for PCBs, EPA circulated the document within the Agency to more than 40 expert Agency scientists who reviewed and commented on the document. In addition, the document was submitted for external peer review to a panel of 16 experts in various areas of PCB toxicity, exposure, and carcinogenicity including a scientist from the General Electric Company (USEPA, 1996b,c). The panel agreed with EPA's conclusions (USEPA, 1996b,c) regarding the carcinogenicity of PCBs and recommended that the Agency use the Brunner et al. (1996) study to develop the cancer slope factor for PCBs. Following review by the Agency and a panel of external reviewers (Koller, 1996), EPA used data from the Brunner et al. (1996) study in the 1996 PCB Cancer Reassessment (USEPA, 1996b). This information was also incorporated into the IRIS file for PCBs (USEPA, 1999b), submitted to Congress in October 1996 and published in an article by the Agency's lead author of the 1996 PCB Cancer Reassessment (Cogliano, 1998).

The 1996 PCB Cancer Reassessment was conducted consistent with the 1996 Proposed Cancer Guidelines (USEPA, 1996a, pp. 6, 55–56), as follows:

> "This new assessment adopts a related approach that distinguishes among PCB mixtures by using information on environmental processes. Environmental processes have profound effects that can decrease or increase toxicity, so toxicity of an environmental mixture is only partly determined by the original commercial mixture. This new assessment, therefore, considers all cancer studies (which used commercial mixtures only) to develop a range of dose-response slopes, then uses information on environmental processes to provide guidance on choosing an appropriate slope for representative classes of environmental mixtures and different exposure pathways."

The 1996 PCB Cancer Reassessment is also consistent with the 1999 Revised Carcinogen Guidelines, which address children's health (USEPA, 1999a). EPA considered data from human epidemiological studies and animal studies in determining that PCBs are probable human carcinogens. In 1988, EPA concluded there was inadequate but suggestive evidence that PCBs cause cancer in humans and sufficient evidence that PCBs cause cancer in animals (USEPA, 1988). In 1996, EPA reaffirmed this classification, concluding (USEPA, 1996b), "Overall, the human studies have been considered to provide limited…to inadequate…evidence of carcinogenicity. The animal studies, however, have been considered to provide sufficient evidence of carcinogenicity" (USEPA, 1996b).

## Human Epidemiological Studies

The peer reviewers of EPA's 1996 PCB Cancer Reassessment found inadequacies in the epidemiological data with regard to limited cohort size, problems in exposure assessment, lack of data on confounding factors, and the fact that occupational exposures may be to different congener mixtures than found in environmental exposures. The peer reviewers stated (USEPA, 1996c):

> "Most researchers think that PCBs act mainly as tumor promoters. Thus, at nontoxic doses, PCBs might be expected to increase cancer risk mainly in humans that have sustained cancer initiation due to exposure to genotoxicants or to the presence of a mutant gene. For common cancers that have complex and multiple etiologies, promotive effects will be seen by epidemiology only if specifically looked for. Epidemiological studies have not thus far tested this hypothesis."

EPA has summarized the human epidemiological studies used to classify PCBs as probable human carcinogens (USEPA, 1996b, 1999b). The human epidemiological evidence is described in USEPA (1999b) as follows (SMR = standard mortality ratio, CI = confidence interval, p = level of statistical significance):

> "Inadequate. A cohort study by Bertazzi et al. (1987) analyzed cancer mortality among workers at a capacitor manufacturing plant in Italy. PCB mixtures with 54%, then 42% chlorine were used through 1980. The cohort included 2100 workers (544 males and 1556 females) employed at least 1 week. At the end of follow-up in 1982, there were 64 deaths reported, 26 from cancer. In males, a statistically significant increase in death from gastrointestinal tract cancer was reported, compared with national and local rates (6 observed, 1.7 expected using national rates, SMR = 346, CI = 141–721; 2.2 expected using local rates, SMR = 274, CI = 112–572). In females, a statistically significant excess risk of death from hematologic cancer was reported, compared with local, but not national, rates (4 observed, 1.1 expected, SMR = 377, CI = 115–877). Analyses by exposure duration, latency, and year of first exposure revealed no trend; however, the numbers are small. A cohort study by Brown (1987) analyzed cancer mortality among workers at two capacitor manufacturing plants in New York and Massachusetts. At both plants the Aroclor mixture being used changed twice, from 1254 to 1242 to 1016. The cohort included 2588 workers (1270 males and 1318 females) employed at least 3 months in areas of the plants considered to have potential for heavy exposure to PCBs. At the end of follow-up in 1982, there were 295 deaths reported, 62 from cancer. Compared with national rates, a statistically significant increase in death from cancer of the liver, gall bladder, and biliary tract was reported (5 observed, 1.9 expected, SMR = 263, $p < 0.05$). Four of these five occurred among females employed at the Massachusetts plant. Analyses by time since first employment or length of employment revealed no trend; however, the numbers are small.
>
> A cohort study by Sinks et al. (1992) analyzed cancer mortality among workers at a capacitor manufacturing plant in Indiana. Aroclor 1242, then 1016, had been used. The cohort included 3588 workers (2742 white males and 846 white females) employed at least 1 day. At the end of follow-up in 1986, there were 192 deaths reported, 54 from cancer. Workers were classified into five exposure zones based on distance from the impregnation ovens. Compared with national rates, a statistically significant excess risk of death from skin cancer was reported (8 observed, 2.0 expected, SMR = 410, CI = 180–800); all were malignant melanomas. A proportional hazards analysis revealed no pattern of association with exposure zone; however, the numbers are small. Other occupational studies by NIOSH (1977), Gustavsson et al. (1986) and Shalat et al. (1989) looked for an association between occupational PCB exposure and cancer mortality. Because of small sample sizes, brief follow-up periods, and confounding exposures to other potential carcinogens, these studies are inconclusive. Accidental ingestion: Serious adverse health effects, including liver cancer and skin disorders, have been observed in humans who consumed rice oil contaminated with PCBs in the "Yusho" incident in Japan or the "Yu-Cheng" incident in Taiwan.

> These effects have been attributed, at least in part, to heating of the PCBs and rice oil, causing formation of chlorinated dibenzofurans, which have the same mode of action as some PCB congeners (ATSDR, 1993; Safe, 1994)."

## Animal Data

EPA determined that PCBs cause cancer in animals based on animal bioassay data. The NTP and IARC also conclude that PCBs are animal carcinogens (NTP, 1981; IARC, 1987). ATSDR's Toxicological Profile (ATSDR, 2000) states, "there is conclusive evidence that commercial PCB mixtures are carcinogenic in animals based on induction of tumors in the liver and thyroid." EPA's evaluation (USEPA, 1996b, 1999b) of the animal bioassay data for PCBs is summarized below:

> "A 1996 study found liver tumors in female rats exposed to Aroclors 1260, 1254, 1242, and 1016, and in male rats exposed to 1260. These mixtures contain overlapping groups of congeners that, together, span the range of congeners most often found in environmental mixtures. Earlier studies found high, statistically significant incidences of liver tumors in rats ingesting Aroclor 1260 or Clophen A 60 (Kimbrough et al., 1975; Norback and Weltman, 1985; Schaeffer et al., 1984). Mechanistic studies are beginning to identify several congeners that have dioxin-like activity and may promote tumors by different modes of action. PCBs are absorbed through ingestion, inhalation, and dermal exposure, after which they are transported similarly through the circulation. This provides a reasonable basis for expecting similar internal effects from different routes of environmental exposure. Information on relative absorption rates suggests that differences in toxicity across exposure routes are small."

## Varying Dose Levels Tested

EPA evaluated a number of animal bioassays regarding the carcinogenicity of PCBs that were conducted at varying dose levels, not only at the Maximum Tolerated Dose (MTD). Consistent with NTP and IARC protocols (NTP, 1984; IARC, 1982, 1987), animal studies are conducted at varying levels below the MTD to aid in establishing a dose-response curve. Data at or near the MTD level were evaluated consistent with EPA's 1986 Carcinogen Guidelines (USEPA, 1986), which state: "Long-term animal studies at or near the MTD are used to ensure an adequate power for the detection of carcinogenic activity."

EPA's 1996 PCB Cancer Reassessment (Table 2-1, USEPA, 1996b), which showed the liver tumor incidences in rats from lifetime exposure studies from 1975 to 1985, generally included a control group of rats not exposed to PCBs and other groups exposed to varying concentrations of PCBs (i.e., 25 ppm, 50 ppm, and 100 ppm). The cited studies include Kimbrough et al. (1975), NCI (1978), Schaeffer et al. (1984), and Norback and Weltman (1985). The Brunner et al. (1996) rat study (later published as Mayes et al., 1998) included doses of PCBs ranging from the control (0 ppm), to 25 ppm, 50 ppm, 100 ppm and 200 ppm. The Brunner et al. (1996) lifetime study data, in which rats were exposed to PCBs at levels less than the MTD for 104 weeks, demonstrated that the rats fed diets of PCBs had statistically significant, dose-related, increased incidences of liver tumors from each Aroclor mixture (USEPA, 1996b).

In addition, the partial lifetime studies that were evaluated by EPA also included exposures to various concentrations of PCBs. Kimbrough et al. (1972) included dose levels of 0 ppm, 20 ppm, 100 ppm, 500 ppm, or 1,000 ppm for Aroclor 1254 or 1260.

Other studies include Kimbrough and Linder (1974), in which BALB/cJ mice were exposed to 300 ppm of Aroclor 1254 for 11 months or for 6 months followed by 5 months without exposure to PCBs. Kimura and Baba (1973) exposed Donryu rats to diets ranging from 38 to 462 ppm of Kanechlor (a trade name for PCBs) 400. Ito et al. (1973) exposed dd mice to 0 ppm, 100 ppm, 250 ppm or 500 ppm of Kanechlor 300, 400 or 500. Ito et al. (1974) exposed Wistar rats to diets of 0, 100, 500, or 1,000 ppm of Kanechlor 300, 400, or 500 ppm. Rao and Banerji (1988) exposed male Wistar rats to diets of 0 ppm, 50 ppm or 100 ppm of Aroclor 1260.

## Gender Differences in Tumors

EPA followed appropriate guidelines and policies in extrapolating the data from the Brunner et al. (1996) rat study to humans. As stated in the PCB Cancer Reassessment (USEPA, 1996b, see p. 44), "the different responses for male and female rats (Brunner et al., 1996) suggest the possibility of developing different potency values for males and females. In view of the 91% response in male Wistar rats (Schaeffer et al., 1984), as well as the sensitivity of male mice (Kimbrough and Linder, 1974; Ito et al., 1973), it is premature to conclude that females are always more sensitive. The PCB Cancer Reassessment (USEPA, 1996b) provides summary tables of the ranges of potency values based on data from both males and females. The potencies are based primarily on the range of Aroclors 1260, 1254, 1242 and 1016 tested in female Sprague-Dawley rats, but other studies were considered also.

## Benign and Malignant Tumors

Consistent with the framework set forth in the Agency's Carcinogen Guidelines (USEPA, 1986, 1996a, 1999a), EPA considered benign as well as malignant tumors in evaluating the carcinogenicity of PCBs because both benign and malignant tumors are considered to be representative of related responses to the PCBs. Benign tumors progressed to malignant tumors in multiple studies.

EPA is not alone in using this approach to evaluate tumor data in assessing the carcinogenicity of chemicals. The Agency's 1996 proposed Carcinogen Guidelines (USEPA, 1996a) noted, "As in the approach of the National Toxicology Program and the International Agency for Research on Cancer, the default is to include benign tumors observed in animal studies in the assessment of animal tumor incidence if they have the capacity to progress to the malignancies with which they are associated. This treats the benign and malignant tumors as representative of related responses to the test agents, which is scientifically appropriate. This is a science policy decision that is somewhat more conservative of public health than not including benign tumors in the assessment. Nonetheless, in assessing findings from animal studies, a greater proportion of malignancy is weighed more heavily than a response with a greater proportion of benign tumors. Greater frequency of malignancy of a particular tumor type in comparison with other tumor responses observed in an animal study is also a factor to be considered in selecting the response to be used in dose response assessment."

With respect to PCB carcinogenicity, in 1996, EPA described a study by Norback and Weltman (1985) that demonstrated tumor progression as follows (USEPA, 1996b):

> "Norback and Weltman (1985). Groups of male or female Sprague-Dawley rats were fed diets with 0 or 100 ppm Aroclor 1260 for 16 months; the latter dose was reduced to 50 ppm for 8 more months. After 5 additional months on the control diet, the rats were killed and their livers were examined. Partial hepatectomy was performed on some rats at 1, 3, 6, 9, 12, 15, 18, and 24 months to evaluate sequential morphologic changes. In males and females fed Aroclor 1260, liver foci appeared at 3 months, area lesions at 6 months, neoplastic nodules at 12 months, trabecular carcinomas at 15 months, and adenocarcinomas at 24 months, demonstrating progression of liver lesions to carcinomas. By 29 months, 91 percent of females had liver carcinomas and 95 percent had carcinomas or neoplastic nodules; incidences in males were lower, 4 and 15 percent, respectively (see table 2–1)."

EPA also evaluated PCB carcinogenicity based on lifetime and stop studies of rats fed diets containing Aroclors 1260, 1254, 1242 or 1016, using data from Brunner et al. (1996). From the lifetime study data, in which rats were exposed to PCBs for 104 weeks, EPA concluded that the rats fed diets of PCBs had statistically significant, dose-related, increased incidences of liver tumors from each Aroclor mixture (USEPA, 1996b; Cogliano, 1998). From the stop study data, in which the rats were exposed to PCBs for 52 weeks and then PCB exposure was stopped, EPA determined that, for Aroclors 1254 and 1242, tumor incidences were approximately half those of the lifetime study; that is, nearly proportional to exposure duration. In contrast, for Aroclor 1016, stop-study tumor incidences were zero, while for Aroclor 1260 they were generally greater than half as many as in the lifetime study.

Earlier studies found high, statistically significant incidences of liver tumors in various strains of rats ingesting Aroclor 1260 or Clophen A60 (Kimbrough et al., 1975, Norback and Weltman, 1985; Schaeffer et al., 1984). Kimbrough et al. (1975) found significantly increased hepatocellular carcinomas in rats fed Aroclor 1260. Schaeffer et al. (1984) found male Wistar rats in the shortest exposed group (16.4 months) had preneoplastic liver lesions, and after 23 months had hepatocellular carcinomas. Norback and Weltman (1985) studied Sprague-Dawley rats exposed to Aroclor 1260 and found that by 29 months 91% of females had liver carcinomas. In addition, the Brunner et al. (1996) study found several of the tumors were hepatocholangiomas, a rare bile duct tumor seldom seen in control rats.

The data from the studies described above are the basis for EPA's determination that PCBs cause cancer in animals. Benign tumors progressed to malignant tumors in multiple studies, in different strains of rats, and at different dose levels of PCBs.

## Cancer Slope Factor (CSF)

The quantification of carcinogenicity is a value called a cancer slope factor (CSF). As outlined in the EPA Carcinogen Guidelines (USEPA, 1986; 1996a), EPA favors basing CSFs on human epidemiological studies, which requires quantitative information on both exposure and response. However, for PCBs, EPA concluded that the human epidemiological data are insufficient to develop CSFs (USEPA, 1996b). During the peer review of EPA's 1996 PCB Cancer Reassessment (USEPA, 1996c), EPA included charge questions to the peer-reviewers requesting specific evaluation of human epidemiological evidence as a basis for developing the CSFs for PCBs. The peer reviewers supported EPA's conclusion that it is not feasible to use the human epidemiological data to develop

CSFs for PCBs (USEPA, 1996c). EPA used the proposed 1996 Carcinogen Guidelines (USEPA, 1996a) to develop the CSFs for PCBs. Following review of the carcinogenicity data and based primarily on the Brunner et al. (1996), EPA developed separate PCB CSFs for inhalation and ingestion, and provided a recommendation for exposure by dermal contact. The oral CSF for PCBs developed in 1988 (USEPA, 1988) was revised downward in 1996 from 7.7 mg/kg-day-1 to 2.0 mg/kg-day–1. In the 1996 PCB Cancer Reassessment (USEPA, 1996b, p. 35), EPA explained,

> "This difference in cancer slope factor is attributable to three factors, each responsible for reducing the slope by approximately one-third: the rat liver tumor reevaluation (Moore et al., 1994), use of the new cross-species scaling factor (USEPA, 1992) and not using a time weighted average dose."

Similarly, when these factors are applied to the CSF derived from the Norback and Weltman (1985) study, the CSF is reduced from 7.7 mg/kg-day–1 to 2.2 mg/kg-day-1.

As part of EPA's 1996 PCB Cancer Reassessment, EPA evaluated an approach regarding PCB congener persistence in the body (Brown, 1994). EPA identified some limitations of using this approach in the development of CSFs for PCBs, as follows (USEPA, 1996b):

> "Reconstruction of past exposure is problematic because different mixtures had been in use over the years, the distribution of exposure and absorption by route and congener is unknown, and congener persistence in the body varies greatly from congener to congener (Brown, 1994) and person to person (Steele et al., 1986)."

## HUMAN EPIDEMIOLOGICAL STUDIES SINCE THE 1996 PCB CANCER REASSESSMENT

Since the 1996 PCB Cancer Reassessment (USEPA, 1996b), additional studies regarding the carcinogenicity of PCBs in humans have been published (e.g., Gustavsson and Hogstedt, 1997; Hardell et al., 1996; Rothman et al., 1997; Tironi et al., 1996; Yassi et al., 1994; Loomis et al., 1997; Kimbrough et al., 1999 [discussed separately]). EPA has noted issues with many of the studies of occupationally exposed individuals working in industrial plants in the U.S. and internationally (USEPA, 1996b). Issues include the small number of tumors found, making it difficult to associate the exposures with specific manufacturing processes in the plant studied by the investigators (i.e., high exposure, medium exposures, or low exposure areas); mortality rather than morbidity as a study objective; the lack of historical data on exposures; and confounding from exposures to chemicals other than PCBs within the plant. A brief summary of the studies and their conclusions regarding the carcinogenicity of PCBs is provided below by type of cancer and population studied.

### Breast Cancer

Recent studies have investigated PCB exposures and breast cancer. EPA has evaluated these studies and concluded that it is not possible to attribute a cause and effect association between PCB exposure and breast cancer given the sparse data available (USEPA, 1997). Study results suggested that PCBs increase the risk of breast cancer after menopause (Moysich et al., 1998) and research has suggested a mechanism by which PCBs can contribute to cancer, including breast cancer (Oakley et al., 1996). Other studies have failed to show an association between PCB exposure and breast cancer (e.g., Hoyer et al., 1998, see studies reviewed in USEPA, 1997 and Table D-1 of USEPA, 2000a).

Researchers have suggested the need to consider PCB levels in women prior to the time of breast cancer diagnosis (e.g., Adami et al., 1995). The critical or sensitive period of exposure for the developing breast tissue may be as an infant or during puberty, in which case the current procedure of measuring blood PCB levels at the time of diagnosis may not be an appropriate biomarker of exposure.

### Organ Sites Excluding Breast Cancer

EPA has also evaluated studies on PCB exposures and cancers other than breast cancer. Based on the available epidemiological evidence, EPA believes that the data are inconclusive with respect to the association of PCBs and cancer in humans, including hepatobiliary, hematological, malignant melanoma, rectal, gastrointestinal tract, pancreatic, and endometrial cancers based on the limitations of the epidemiological studies (USEPA, 1999b).

### Kimbrough et al. (1999a) Occupational Study

In 1999, Dr. Kimbrough and colleagues published a study of cancer mortality in workers exposed to PCBs (Kimbrough et al., 1999a). The paper describes a study of workers from two GE capacitor manufacturing plants in New York State. In this study, mortality (deaths) from all cancers was determined for 7,075 females and males who worked at the GE facilities for at least 90 days between 1946 and 1977. The total number of deaths from all causes was 1,195 people, and the total number of deaths caused by cancer was 353 people. No significant elevations in mortality for any site-specific cause were found in the hourly worker cohort (i.e., group). No significant elevations were seen in the most highly exposed workers. Mortality from all cancers was significantly below expected in hourly male workers and comparable to expected for hourly female workers. Several researchers submitted Letters to the Editor identifying limitations of the Kimbrough et al. (1999a) study, which were published in the Journal of Occupational and Environmental Medicine (Bove et al., 1999; Frumkin and Orris, 1999). The response to these letters was also published (Kimbrough et al. (1999b).

EPA performed a preliminary review of the Kimbrough et al. (1999a) study and identified aspects of the study that suggest that the study will not change the Agency's conclusions regarding the carcinogenicity of PCBs (USEPA, 2000a–c). The primary limitation, which is shared by other similar epidemiological studies, is that the degree of exposure is not well characterized. As part of its review, EPA sent copies of the Kimbrough et al. (1999a) paper to several researchers requesting an evaluation regarding whether this new paper would change the Weight of Evidence classification of PCBs as probable human carcinogens. The findings from these letters are summarized below:

### Dr. D. Ozonoff of the Boston University School of Public Health concluded (Ozonoff, 1999):

"In short, we have here another "data point". It should be judiciously interpreted and used with the caution appropriate to studies of this type. In particular, this means not giving undue weight to its failure to show associations previously revealed, since there are too many factors that would mitigate against being able to show them in this study."

### Dr. M. Harnois of the Massachusetts Department of Environmental Protection concluded (Harnois, 1999):

"A subgroup that is masked in this study is the one containing hourly male workers exposed to Aroclor 1254 by dermal contact, incidental ingestion, and inhalation for at least 5 years and followed for at least 20 years. This group could have different cancer frequencies from those presented in the report, being definitely exposed to a known carcinogenic mixture for a prolonged interval and observed for an interval that could allow development of tumors.

This report deals mostly with deaths due to cancer effects, but we know that reproductive, nervous and immunological effects can also occur. These are beyond the scope of the research report, but may be ignored by readers who assume that cancer is the only effect of PCBs."

### Dr. T. Mack of the University of Southern California, Norris Comprehensive Cancer Center concluded (Mack, 1999):

"I guess my bottom line is that the summary statements ("lack of any significant elevations adds important information" and "lack of consistent findings—would suggest a lack of an association") in the paper are appropriate. I think that it is appropriate to downgrade the priority given to PCB's. However, based on the animal studies (and recognizing a. the possibility limited relevance to man and b. the absence of any confirmation of liver cancer in humans) and on this very small amount of information pointing to colorectal tumors, I don't think that this potential carcinogenicity of PCB's can be completely dismissed. I recognize the flimsiness of the evidence, and that a less conservative person could persuasively argue the other way."

### The ATSDR Toxicological Profile for PCBs (ATSDR, 2000) summarizes the limitations of the exposure information from Kimbrough et al., (1999a) as follows:

"PCB exposures were predominantly to Aroclor 1254 from 1946 to 1954, Aroclor 1242 from 1954 to 1971, and Aroclor 1016 from 1971 to 1977. Exposures were qualitatively classified as high, low, or undefinable based on types and locations of jobs and some area measurements. No personal exposure monitoring was performed, although previously reported data on 290 self-selected workers from one of the plants had serum PCBs levels in ranges of 6 to 2,530 and 1 to 546 ppb for lower and higher chlorinated homologs, respectively (Wolff et al., 1982). Workers with high exposure jobs had direct PCB contact (dermal and/or inhalation), workers with lower exposure jobs primarily had inhalation exposure to background levels of PCBs in the plant, and workers with undefinable exposures had exposures that varied depending on whether tasks were performed. Exposure-specific analysis was limited to workers with the greatest potential for exposure (i.e., hourly workers who ever worked in a high exposure job, worked for at least 6 months in a high-exposure job, worked for at least 1 year in a high-exposure job). Workers who exclusively worked in high-exposure jobs could not be analyzed as a separate group due to small numbers (112 males, 12 females)."

### The Toxicological Profile for PCBs concluded (ATSDR, 2000):

"Interpretation of the Kimbrough et al. (1999a) findings is complicated by a few study limitations and biases, including some exposure misclassifications related to use of length of employment alone as a surrogate of exposure, potentially insufficient dosage differences between exposed and

> comparison groups, a degree of selection bias due to the healthy worker effect that may have resulted in an under estimate of SMRs, concern for low statistical power due to the small number of deaths from site-specific cancers in some of the group (e.g., female hourly workers with high exposure and > 20 years latency), relatively young age at follow-up, and use of the general population for comparison rather than an internal control group or a group of workers from another company. These issues are discussed by Bove et al. (1999), Frumkin and Orris (1999), and Kimbrough et al., (1999b). Some of the limitations are typical of occupational cohort mortality studies, and strengths of the study include its size (the largest cohort of PCB workers ever studied) and essentially complete follow-up of long duration. Unresolved are the puzzling Kimbrough et al. (1999a) findings of significantly lower than expected mortality from all cancers among males and the lower number of observed cases of liver and biliary tract cancers among females compared to the smaller cohort studies by Brown et al. (1987), a subset of the same study population. These unresolved findings suggest that ascertainment of cancer mortality was not completed in this study. Overall, the study limitations are sufficient to cast doubt on the negative findings for liver and biliary tract cancer and other site-specific cancers."

In light of the information summarized above regarding the limitations of the Kimbrough et al. (1999a) study, which are similar to the limitations of other human epidemiological studies, EPA has not changed its Weight of Evidence classification of PCBs as probable human carcinogens.

## EPA'S PCB RESEARCH

EPA has conducted significant research on PCBs and the mechanisms of PCB action. Following is a partial list of research conducted by EPA's Office of Research and Development from 1996 to 2000. In addition, EPA has worked with other federal agencies through programs such as the Superfund Basic Research Program (part of the National Institute of Environmental Health Sciences) to fund research on PCB toxicity through grants to a number of Universities (Massachusetts Institute of Technology, State University of New York-Albany, University of Kentucky, etc.) that are evaluating PCB toxicity.

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## HUDSON RIVER PCBS SITE

IRIS toxicity values undergo an extensive internal and external peer review process (USEPA, 1996b,c and 1999b) and are thus the preferred toxicity values for use in Superfund risk assessments (USEPA, 1989, 1993, 1996b,c). The use of IRIS data in the evaluation of the toxicity of chemicals at Superfund sites addresses EPA's goal of using consistent toxicity information in risk assessments at Superfund sites across the country.

Consistent with EPA's risk assessment guidance (USEPA, 1989, 1990, 1993), in the HHRA for the Hudson River PCBs Site, EPA evaluated newer studies of PCB toxicity (USEPA, 2000a,b). Based on this review, EPA determined that these newer studies would not change the conclusions of the 1996 PCB Cancer Reassessment (i.e., that PCBs are probable human carcinogens) and that it was appropriate to use the toxicity information and CSFs in IRIS in the Site-specific risk assessment (USEPA, 1996b,c; 2000a-d).

The peer reviewers for the HHRA agreed with EPA's use of the toxicity information in IRIS, but recommended that EPA provide an update of the data to identify recently published studies (ERG, 2000). In response, EPA updated the list of human epidemiology studies in Appendix D of the Revised HHRA (USEPA, 2000a). EPA identified a number of limitations with these newer human epidemiological studies similar to those identified in the IRIS file for PCBs (USEPA, 1999a), including lack of sufficient exposure information, failure to adequately account for co-exposure to other compounds, and inconsistency between study results.

EPA recognizes that environmental processes can alter the congener composition of a PCB mixture in the environment. The CSFs in IRIS are based on studies using a number of different Aroclor mixtures (i.e., the commercial formulation of PCBs including Aroclor 1016, 1242, 1254, and 1260), which together span the range of congeners most frequently found in environmental mixtures (USEPA, 1996b). IRIS provides for using a lower CSFs for risk calculations when congener analysis demonstrates a predominance of the lower chlorinated congeners (i.e., when congener or isomer analysis verifies that congeners with more than four chlorine atoms comprise less than 1/2 percent of the total PCBs). This lower CSF was not used in the HHRA based on congener analysis of Hudson River fish.

### Dioxin-Like PCBs

Consistent with EPA guidance and procedures (USEPA, 1996b), the revised HHRA (USEPA, 2000a) evaluated cancer risks from exposure to dioxin-like PCBs using the latest scientific consensus on TEFs for dioxin-like PCBs (USEPA, 1996b), as an additional consideration for the risk manager. Risks from dioxin-like PCBs were not combined with non-dioxin-like PCBs, based on EPA's ongoing effort to develop a procedure for combining these cancer risks to avoid potential double counting.

### Effect of PCB Exposure on Blood Levels

EPA followed risk assessment guidance and procedures (USEPA, 1989, 1990, 1993, 1996b) to quantify cancer risks to individuals exposed to PCBs at the Hudson River PCBs Site in the HHRA (USEPA, 2000a). The approach used in the HHRA is different than measurement of blood PCB levels in former capacitor workers. First, the HHRA evaluates current and future exposures, while the data on PCB levels in blood integrates past exposure. Second, capacitor workers were primarily exposed through dermal contact and inhalation of PCBs, whereas anglers, which had the highest cancer risks evaluated in the HHRA, would be exposed to PCBs through ingestion of contaminated fish caught in the Hudson River. Third, in the HHRA EPA evaluated cancer risks to the RME individual, whereas for capacitor workers the level of exposure is generally not known. Fourth, the PCB congener profile in the capacitor plant is likely to be different from the congener profile of PCBs that are bioaccumulated in the fish. Lastly, EPA is concerned with potential exposures to the human population including sensitive groups that may include the fetus exposed from mothers who consumed PCB-contaminated fish, infants exposed to PCBs through breast milk, young children, adolescents, adults, and individuals with pre-existing medical conditions (USEPA, 2000a); many of these sensitive groups may not be represented in a healthy worker population. As stated in EPA's 1996 PCB Cancer Reassessment (USEPA, 1996b):

> "people with decreased liver function, including inefficient glucuronidative mechanism in infants, can have less capacity to metabolize and eliminate PCBs (Calabrese and Sorenson, 1977).

> Additionally, approximately 5% of nursing infants receive a steroid in human milk that inhibits the activity of glucuronyl transferase, further reducing PCB metabolism and elimination (Calabrese and Sorenson, 1977)."

Differences between occupational exposures and exposure through ingestion of contaminated fish were discussed in the 1996 PCB Cancer Reassessment (USEPA, 1996b). Notably, a study of people exposed through eating contaminated fish (Hovinga et al., 1993) suggests that the PCB mixtures in fish can be more persistent than those to which the workers were exposed. From 1977 to 1985, mean PCB serum levels (quantified using Aroclor 1260 as a reference standard) from 111 Great Lakes fish eaters decreased only slightly from 20.5 to 19.0 ppb. This indicates that the rate of decline in the fish eating populations will be slower than that for the workers. ATSDR's Toxicological Profile (ATSDR, 2000) states that there are no known treatment methods for reducing body burdens of PCBs, concluding that limiting or preventing further exposures appears to be the most practical method for reducing PCB body burdens.

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# WHITE PAPER NO. 13 – HUDSON RIVER RECORD OF DECISION
# PCB NON-CANCER HEALTH EFFECTS WHITE PAPER

***Response to a Review of***

## DRAFT BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT
## FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN
## REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

October 2001

***This Document has been Prepared by***

United States Environmental Protection Agency

**December 2002**

# White Paper No. 13 –
# Hudson River Record of Decision
# PCB Non-Cancer Health Effects White Paper

The white paper contained in this attachment was prepared as part of the Record of Decision for the Hudson River in New York. The topic of focus – PCBs as non-carcinogens – has relevance to the Lower Fox River and Green Bay site and the response to comments received on the Baseline Human Health and Ecological Risk Assessment and are defended by WDNR and EPA.

## PCB Non-Cancer Health Effects (ID362704)

### Abstract

Non-cancer health effects associated with exposure to PCBs include reduced birth weight, learning problems, and reduced ability to fight infection. The quantification of non-cancer health effects is a Reference Dose, which is a dose below which non-cancer health effects are not expected to occur over a lifetime. EPA has established guidelines for evaluating non-cancer health effects and developing Reference Doses for chemicals. These guidelines were externally peer reviewed. Using these guidelines and associated documents, EPA developed a Reference Dose for Aroclor 1016, which was externally peer reviewed. EPA used the same methodology to develop a Reference Dose for Aroclor 1254, which was internally peer reviewed. EPA's Reference Dose for Aroclor 1254 is consistent with the chronic Minimal Risk Level for PCBs developed by the Agency for Toxic Substances and Disease Registry. EPA is currently updating the non-cancer toxicity information for PCBs contained in the Integrated Risk Information System, which is the Agency's consensus database of toxicity information.

In the Human Health Risk Assessment for the Hudson River PCBs Site, EPA summarized recent studies published since 1994, including studies on developmental/neurotoxic effects, thyroid and immunological effects, reproductive effects, and neurological effects in adults. Based on a review of these studies, EPA determined that it was appropriate to use the current Reference Doses for PCBs in the Human Health Risk Assessment. EPA submitted the Human Health Risk Assessment for external peer review, and the peer reviewers agreed with the toxicity values used in the Human Health Risk Assessment.

### Introduction

The purpose of this paper is to provide an overview of EPA's process for evaluating the noncancer toxicity of a chemical, development of non-cancer Reference Doses (RfDs) for PCBs, and the application of this toxicity information in the Human Health Risk Assessment for the Hudson River PCBs Site.

This paper is divided into three parts. The first part describes EPA's non-cancer guidelines and background documents for developing reference doses (RfDs) (USEPA, 1986a-b, 1991, 1992, 1993a,b, 1996a, 1998). These documents set forth principles and procedures for evaluating noncancer toxicity information.

The second part of this paper describes the Agency's evaluation of the non-cancer toxicity of PCBs. It summarizes the important studies regarding PCB non-cancer toxicity, including the critical studies identified for development of the Reference Doses in the Integrated Risk Information System (IRIS), the Agency's consensus database of toxicity information. The third part describes the non-cancer toxicity information used in the Human Health Risk Assessment for the Hudson River PCBs Site and addresses the Averaging Times and blood PCB levels from occupational studies.

## EPA'S NON-CANCER GUIDELINES AND REFERENCE DOSE DEVELOPMENT

EPA's process for evaluating human epidemiological and animal evidence to determine the noncancer toxicity of chemicals, including PCBs, is set forth in the Agency's guidelines (USEPA, 1986a-b, 1991, 1992, 1993a, 1996a, 1998) and supporting information (USEPA, 1993b; Barnes and Dourson, 1988; Dourson and Stara, 1983). The guidelines cover a variety of health endpoints including developmental toxicity (USEPA, 1991), reproductive toxicity (USEPA, 1996a), neurotoxicity (USEPA, 1998), female reproductive risk (USEPA, 1986a) and male reproductive risk (USEPA, 1986a).

The non-cancer toxicity guidelines were developed within the Agency and published in the Federal Register for comment. Periodically, the guidelines have been updated to reflect new scientific understanding regarding toxicity. Prior to being finalized, the guidelines, as updated, are externally peer reviewed by a panel of expert scientists in the various fields associated with non-cancer toxicity including developmental toxicity, neurological toxicity, endocrine effects, who work in universities, environmental groups, industry, labor, and other governmental agencies. EPA responds to comments on the draft guidelines and makes changes based on a review of the comments submitted by these groups or individuals. The guidelines are also submitted for review to EPA's Science Advisory Board, an external scientific review panel.

### Reference Dose Development

The quantification of chronic non-cancer health effects is a chronic Reference Dose (RfD), which is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of an exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (USEPA, 1989, 1993b).

The procedures used by EPA to develop RfDs are provided in the Background Document on RfD Development available on EPA's IRIS database (USEPA, 1993b; see also www.epa.gov/iris). In general, exposure to a given chemical, depending on the dose, may result in a variety of toxic effects ranging from death to subtle biochemical, physiologic, or pathologic changes. The process for RfD development includes:

- Critical evaluation of the available scientific literature, including human epidemiological and animal toxicity studies. Human data are often useful in qualitatively establishing the presence of an adverse effect in exposed human populations. Human epidemiological studies may be limited in their ability to establish a dose-response relationship between level of exposure and observed health effects, by the degree to which confounders (e.g., other chemicals and lifestyle factors) are controlled.

- For many chemicals, the principal studies are drawn from experiments conducted on nonhuman mammals, such as the rat, mouse, rabbit, guinea pig, hamster or monkey. These animal studies typically reflect situations in which exposure to the chemical has been carefully controlled and the problems of heterogeneity of the exposed population and concurrent exposures to other chemicals have been minimized.

- EPA uses a weight-of-evidence approach in evaluating the non-cancer toxicity of a chemical, with emphasis on the results from the principal and supportive studies. Identification of the critical study(s), critical effect(s) and a dose level (i.e., no observed adverse effect level [NOAEL] or lowest observed adverse effect level [LOAEL]) based on the study(s). The dose level is then divided by uncertainty factors to calculate an RfD. In general, the values used for each uncertainty factor are either 1, 3, or 10 (USEPA, 1993b). The value of 3 is used as a "half" factor and represents the square root (rounded to one significant digit) of the full uncertainty factor of 10, so that two "half" factors yield a full factor of 10 when multiplied together (USEPA, 1994b).

- There are four standard uncertainty factors (ranging from 1 to 10) that can be used when calculating an RfD. These factors account for 1) the variation in sensitivity among members of the human population, 2) extrapolation from animal data to humans, 3) extrapolation from less than chronic NOAELs to chronic NOAELs, and 4) extrapolation from LOAELs to NOAELs. An additional modifying factor (MF), also ranging from 1 to 10, can be applied to the calculation of the RfD. The magnitude of the MF depends upon an assessment of the scientific uncertainties of the study and the database used in deriving the RfD that are not explicitly treated above, such as completeness of the overall database and the number of species tested.

The equation used in the calculation is:

$$RfD = NOAEL \div \left(UF \times MF\right).$$

## NON-CANCER TOXICITY OF PCBS

Based on a weight of the evidence, EPA concluded that PCBs pose a non-cancer health hazard. Non-cancer health effects associated with exposure to PCBs include dermal effects (e.g., chloracne), developmental neurotoxic effects (e.g., learning problems), ocular effects (eye problems), reduced birth weight, and immunotoxic effects (e.g., reduced ability to fight infection). This conclusion is based primarily on animal studies, including monkey studies. Human evidence was also considered.

EPA is not alone in its concern regarding the non-cancer toxicity of PCBs and in using data from studies in monkeys to develop health protective toxicity values. In a joint publication with EPA, ATSDR stated (ATSDR and USEPA, 1996):

> "The findings of elevated PCB levels in human populations, together with findings of developmental deficits and neurologic problems in children whose mothers ate PCB-contaminated fish, have compelling implications. The weight of evidence clearly indicates that populations continue to eat fish containing PCBs and that significant health consequences are associated with consumption of large amounts of some fish…Human health studies…indicate that: 1) reproductive function may be disrupted by exposure to PCBs; 2) neurobehavioral and developmental deficits occur in newborns and continue through school-aged children who had in utero exposure to PCBs; 3) other systemic effects (e.g., self-reported liver disease and diabetes, and effects on the thyroid and immune systems) are associated with elevated serum levels of PCBs; and 4) increased cancer risks, e.g., non-Hodgkin's lymphoma, are associated with PCB exposures."

The National Research Council (NAP, 2000) concluded:

> "The Committee's review of recent scientific information supports the conclusion that exposure to PCBs may result in chronic effects (e.g., cancer, immunological, developmental, reproductive, and neurological effects) in humans and/or wildlife. Therefore, the committee considers that the presence of PCBs in sediments may pose long-term public health and ecosystem risks."

## Dermal Effects

Several studies document dermal effects in workers exposed to PCBs (Fischbein et al., 1979, 1982, 1985; Maroni et al., 1981a,b; Ouw et al., 1976; Smith et al., 1982). Dermal effects include skin rashes, pigmentation disturbances of skin and nails, thickening of the skin, burning sensations, and chloracne, a severe form of acne that results from exposure to PCBs. Variability in response in more highly exposed individuals suggests that susceptibility varies greatly among individuals (ATSDR, 2000).

Studies in Rhesus monkeys fed diets containing Aroclors for intermediate durations of exposure found effects including facial edema (swelling), acne, folliculitis (inflammation of the hair follicle) and alopecia (hair loss) (Allen and Norback, 1973, 1976; Allen et al. 1973, 1974a,b; Barsotti et al., 1976; Becker et al., 1979; Ohnishi and Kohno, 1979; Thomas and Hinsdill, 1978).

## Developmental/Neurotoxic Effects

Developmental/neurotoxic effects associated with PCB exposure in animals and identified in human epidemiological studies include reduced birth weight, learning problems, and memory problems.

On September 14 and 15, 1992, EPA convened a Risk Assessment Forum (RAF) Colloquium of expert scientists to evaluate the developmental/neurotoxic effects of PCB exposure. The Workshop papers discuss the principles and methods for evaluating data from animal and human epidemiological studies (USEPA, 1993a). The report concluded:

> "The sense of the meeting seemed to be that, at least in qualitative terms, the available data are sufficient. In other words, based on an evaluation of the strengths and weaknesses in the data and on the consistency of effects seen in all species tested, including humans, there is sufficient

> information to indicate that PCBs cause developmental neurotoxicity. Interestingly, the data suggest that prenatal exposure to PCBs may be more detrimental than postnatal exposure, even though the level of exposure via breast milk is much greater than that occurring via placental transfer."

Similarly, ATSDR's Toxicological Profile for PCBs (ATSDR, 2000) stated:

> "Studies in humans who consumed high amounts of Great Lakes fish contaminated with environmentally persistent chemicals, including PCBs, have provided evidence that PCBs are important contributors to subtle neurobehavioral alterations observed in newborn children and that some of these alterations persist during childhood…Neurobehavioral alterations have been also observed in rats and monkeys following pre- and/or postnatal exposure to commercial Aroclor mixtures, defined experimental congener mixtures, single PCB congeners, and Great Lakes contaminated fish. In addition, monkeys exposed postnatally to PCB mixtures of congeneric composition and concentration similar to that found in human breast milk showed learning deficits long after exposure had ceased."

## Immunotoxic Effects

The immune system is the body's primary defense against infection. Immune effects associated with PCBs include a reduced ability to fight infections. Several human epidemiological studies evaluated the effects of PCBs on workers and found transient effects on total and differential white blood cell counts (Chase et al., 1982; Lawton et al., 1985; Maroni et al., 1981b; Smith et al., 1982). A number of studies have evaluated the effects of PCBs in specific population groups (i.e., infants, children of mothers who consumed fish, and fish consumers). Immunotoxic effects reported in the Great Lakes populations include increased middle ear and respiratory tract infections in children of exposed mothers (Smith, 1984).

ATSDR (2000) concluded:

> "Findings include increased susceptibility to respiratory tract infections in adults and their children, increased prevalence of ear infections in infants, decreased total serum Immunoglobulin A and Immunoglobulin M antibody levels, and/or changes in T lymphocyte subsets. Overall there is a consistent of effects among the human studies suggesting sensitivity of the immune system to PCBs, particularly in infants expose in utero and/or via beast feeding. However, due to the mixed chemical nature of the exposures and generally insufficient information on exposure-response relationship, the human studies provide only limited evidence of PCB immunotoxicity."

Decreased antibody responses (Immunoglobulin G and Immunoglobulin M) were detected in studies on monkeys (Tryphonas et al., 1989, 1991a,b).

## Ocular Effects

Occupational studies have shown eye irritation, tearing and burning among workers exposed to airborne PCBs (Emmett et al., 1988, Ouw et al., 1976; and Smith et al., 1982). Fischbein et al. (1979, 1985) found that some capacitor workers had edema of the upper eyelid, congestion of the conjunctiva, eye discharge and enlargement of the Meibomian glands following exposures to various Aroclors in a range of concentrations.

The monkey studies noted ocular exudate (discharge) and inflamed and enlarged Meibomian glands (Arnold et al., 1993a, b).

## Reference Doses for Aroclors 1016 and 1254

Using the process summarized above, EPA evaluated both human epidemiological evidence and animal toxicity studies in developing quantitative RfDs for Aroclors 1016 and 1254 (USEPA, 1999a,b).

EPA determined that the human data available for risk assessments of Aroclor 1016 and Aroclor 1254 are useful only in a qualitative manner, noting, "Studies of the general population exposed to PCBs by consumption of contaminated food, particularly neurobehavioral evaluations of infants exposed in utero and/or through lactation, have been reported, but the original PCB mixtures, exposure levels and other details of exposure are not known (Kreiss et al., 1981; Humphrey, 1983; Fein et al., 1984a,b; Jacobson et al., 1984a,b, 1985, 1990a,b; Rogan et al., 1986; Gladen et al., 1988). Most of the information on health effects of PCB mixtures in humans is available from studies of occupational exposure. Some of these studies examined workers who had some occupational exposure, but in these studies concurrent exposure to other Aroclor mixtures nearly always occurred, exposure involved dermal as well as inhalation routes (the relative contribution by each route was not known), and monitoring data were lacking or inadequate (Fischbein et al., 1979, 1982, 1985; Fischbein, 1985; Warshaw et al., 1979; Smith et al., 1982; Lawton et al., 1985)."

A brief summary of EPA's development of the RfDs is provided below.

## Aroclor 1016

EPA identified the monkey reproductive studies by Barsotti and van Miller (1984) and neurological studies by Levin et al. (1988), and Schantz et al. (1989, 1991) as critical studies. The critical effect identified was reduced birth weights. A NOAEL of 0.25 ppm in feed (or 0.007 mg/kg-day) was identified. The IRIS chemical file for Aroclor 1016 summarizes the critical study and effect and describes EPA's evaluation of a number of other studies that provide supporting information for the selection of these studies (USEPA, 1999a; see also www.epa.gov/iris).

As part of EPA's peer review process, on May 24 and 25, 1994, EPA convened an RAF Workshop to assess whether the Reference Dose (RfD) for Aroclor 1016 (USEPA, 1994a) represents a full consideration of the available scientific data and whether that analysis is clearly articulated in the RfD entry on IRIS. The results from this Workshop were used in finalizing the Responsiveness Summary Hudson River PCBs Site Record of Decision PCB Non-Cancer Health Effects-7 RfD for Aroclor 1016 (USEPA, 1999a) currently listed on IRIS. The IRIS chemical files for both Aroclor 1016 (USEPA, 1999a) and Aroclor 1254 (USEPA, 1999b) represent the consensus of the Reference Dose/Reference Concentration Workgroup, responsible for reaching consensus on non-cancer toxicity values, which was in existence when the files were completed. USEPA's applied uncertainty/modifying factors totaling 100 (3 x 3 x 3 x 3 and rounded) to be protective of sensitive human populations that may be exposed i.e., the NOAEL of 0.007 mg/kg-day was divided by a factor of 100 to yield a RfD of 0.00007 mg/kg-day. A summary of the UFs and their basis is provided below:

- A factor of 3 is applied to account for sensitive individuals. The results of these studies, as well as data for human exposure to PCBs, indicate that infants exposed transplacentally represent a sensitive subpopulation.

- A factor of 3 is applied for extrapolation from Rhesus monkeys to human. A full 10-fold factor for interspecies extrapolation is not considered necessary because of similarities in toxic responses and metabolism of PCBs between monkeys and humans and the general physiologic similarity between these species. In addition, the Rhesus monkey data are predictive of other changes noted in human studies such as chloracne, hepatic changes, and effects on reproductive function.

- A factor of 3 is applied because the study duration was considered as somewhat greater than subchronic, but less than chronic; a partial factor of 3 is used to account for extrapolation from a subchronic exposure to a chronic RfD.

- A factor of 3 is applied because of limitations in the database. Despite the extensive amount of animal laboratory data and human epidemiologic information regarding PCBs, the issue of male reproductive effects is not directly addressed and two-generation reproductive studies are not available.

### Aroclor 1254

EPA identified the monkey studies by Arnold et al. (1993a,b), Tryphonas et al. (1989, 1991a,b) as the critical studies. The critical effects were ocular exudate, inflammation and prominent Meibomian glands in the eye, distorted growth of finger- and toenails, and decreased antibody responses (Immunoglobulin G and Immunoglobulin M) based on responses to sheep erythrocytes (USEPA, 1999b). A NOAEL could not be identified so a LOAEL of 0.005 mg/kg-day was identified.

EPA applied uncertainty factors totaling 300 (i.e., 10 x 3 x 3 x 3 and rounded) to the LOAEL of 0.005 mg/kg and calculated an RfD of 0.00002 mg/kg-day. The basis for the UFs are provided below:

- A factor of 10 is applied to account for sensitive individuals such as children, elderly, and others.

- A factor of 3 is applied to extrapolation from Rhesus monkeys to humans. A full 10-fold factor for interspecies extrapolation is not considered necessary because of similarities in toxic responses and metabolism of PCBs between monkeys and humans and the general physiologic similarity between these species. Tilson et al. (1990) reported that humans appear to be more sensitive than monkeys or rodents. EPA noted that the differences in species sensitivity may be related to variations in the sensitivity of the testing paradigms used in different species, and/or differences in the toxicity of the various commercial mixtures, or environmental exposures used in various studies (USEPA, 1993a). Based on similarity in types of effects but dissimilarity in effective doses and NOAELs across test species, EPA concluded that monkeys are not less sensitive than humans with respect to developmental/neurotoxic effects of PCBs (USEPA, 1993a).

- A factor of 3 is applied for the use of a minimal LOAEL since the changes in the periocular tissues and nail bed seen at the 0.05 mg/kg-day are not considered to be of marked severity. The duration of the critical study continued for approximately 25% of the lifespan of Rhesus monkeys, so a factor of 3 is appropriate for extrapolation from subchronic exposure to a chronic RfD.

- A factor of 3 is applied based on the immunologic and clinical changes that were observed but did not appear to be dependent upon duration, which further justifies using a factor of 3 rather than 10 for extrapolation from subchronic to chronic, lifetime exposure. The Agency for Toxic Substances and Disease Registry issued an updated Toxicological Profile for Polychlorinated Biphenyls following external peer review (ATSDR, 2000). ATSDR (2000) includes Minimal Risk Levels (MRL). The MRL is defined as "an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure" (ATSDR, 2000). The chronic MRL is developed to be protective over a one-year period or more, and is similar to EPA's RfD, which is developed to be protective over a lifetime. The intermediate MRL is developed to be protective from 15 to 364 days.

ATSDR's chronic MRL is 0.00002 mg/kg-day, based on the study by Tryphonas et al. (1989, 1991a,b), which also was used as the critical study for EPA's RfD for Aroclor 1254. The intermediate oral MRL level developed by ATSDR based on monkey studies by Rice (1997, 1998, 1999b) and Rice and Hayward (1997 and 1998) is 0.00003 mg/kg-day, which is slightly higher than the MRL for chronic exposure (ATSDR, 2000). Similar to EPA, ATSDR used a factor of 3 for extrapolating from the monkey studies to humans in developing its MRLs.

## HUDSON RIVER PCBS SITE

Consistent with EPA guidance and CERCLA and NCP policies, the PCB non-cancer toxicity information and RfDs that are in IRIS were used in the HHRA (USEPA, 2000a,b). The use of IRIS data in the evaluation of chemical toxicity at Superfund sites addresses EPA's goal of using consistent toxicity information at Superfund sites across the country.

EPA submitted the HHRA (USEPA, 1999c) for external peer review. EPA specifically charged the peer reviewers to evaluate whether use of the IRIS values was appropriate. The peer Responsiveness Summary Hudson River PCBs Site Record of Decision PCB Non-Cancer Health Effects-9 reviewers for the HHRA agreed with USEPA's use of non-cancer toxicity information from IRIS.

In the HHRA, EPA applied an Averaging Time that is equivalent to the Exposure Duration multiplied by 365 days/year, consistent with USEPA (1989). The peer reviewers of the HHRA agreed with EPA's selection of Averaging Times (USEPA, 2000b) and recommended that EPA evaluate the effects of PCBs to pregnant and nursing women using a shorter exposure duration. The non-cancer hazards to the fetus and infant were addressed qualitatively in the HHRA (USEPA, 2000a), due to the lack of an approved methodology for modeling the effects of PCBs on the fetus and calculating the PCB levels in breast milk based on the mother's body burden.

The HHRA peer reviewers also recommended that EPA also provide a discussion of the more recently published studies on non-cancer endpoints to determine what effect these studies might have on risk estimates. In response, in the Revised HHRA, EPA summarized a number of newly published human epidemiological studies on the non-cancer effects of PCBs (including updates of the neuro-developmental studies in cohorts of children and adults) identified in the IRIS files for Aroclors 1016 and 1254 (USEPA, 2000a). Based on an evaluation of this data, EPA concluded that the toxicity values in IRIS are still appropriate for the HHRA (USEPA, 2000b).

Since 1994, a number of new animal studies and human epidemiological studies and updated studies of the cohorts originally described in 1993-1994 have been published (e.g., Rice 1997, 1998, 1999b, Rice and Hayward, 1997, 1998; Schantz, 1996, Schantz et al., 2001; Jacobson and Jacobson, 1996a,b; 1997; Lanting et al., 1998a,b,c; Patandin et al., 1998, 1999a,b; Koopman-Esseboom et al., 1996; Weisglas-Kuperus et al., 1995, 2000; and Fitzgerald et al., 1995, 1996, 1998, 1999). The studies have been published in a variety of peer-reviewed journals (e.g., Neurotoxicology, New England Journal of Medicine, Science, Lancet, Environmental Health Perspective, Journal of Pediatrics), including a number of public health and epidemiological journals (American Journal of Public Health, Annals of Epidemiology, Epidemiology, American Journal of Epidemiology). In general, as the studies progressed through time, the list of confounders were expanded or reduced as appropriate based on a priori information regarding previous studies, consistent with epidemiological practices. A summary of these studies is provided the HHRA (USEPA, 2000a).

Some of these studies found reductions in IQ points (i.e., 3 to 5 points across the various studies) based on prospective studies in children exposed to various sources of PCBs, including fish consumption. At a population level, as well as at an individual level, the potential impacts of the loss of IQ points may be significant, especially among children at the low end of the IQ distribution.

As part of EPA's reassessment of PCB non-cancer toxicity, EPA will critically evaluate this new information (e.g., from human epidemiological studies, animal studies, and mechanistic data) to determine the critical study, critical effect, and appropriate Uncertainty/Modifying Factors necessary to develop a new RfD or reaffirm the current RfD. Documents summarizing the noncancer toxicology of PCBs will be reviewed within the Agency, and submitted for external peer review. Based on the results of this review, an IRIS chemical file will be developed and undergo internal EPA consensus IRIS review, and will be made available on the IRIS database at the completion of this process.

### Effects of PCB Exposure on Blood Levels

EPA followed risk assessment guidance and procedures (see National Contingency Plan; see also USEPA, 1989, 1993c, 1995, 1997) to quantify non-cancer health hazards to individuals exposed to PCBs at the Hudson River PCBs Site in the HHRA (USEPA, 2000a). The approach used in the HHRA is different than measurement of PCB levels in blood of former capacitor workers.

First, the HHRA evaluates current and future exposures, while the blood PCB level data integrates past exposure. Second, capacitor workers were primarily exposed through dermal contact and inhalation of PCBs, whereas anglers, which had the highest cancer risks evaluated in the HHRA, would be exposed to PCBs through ingestion of contaminated fish caught in the Hudson River. Third, in the HHRA EPA evaluated non-cancer health hazards to the RME individual, whereas for capacitor workers the level of exposure is generally not known. Fourth, the PCB congener profile in the capacitor plant is likely to be different from the congener profile of PCBs that are bioaccumulated in the fish. Lastly, EPA is concerned with potential exposures to the human population including sensitive groups that may include the fetus exposed from mothers who consumed PCB-contaminated fish, infants exposed to PCBs through breast milk, young children, adolescents, adults, and individuals with pre-existing medical conditions (USEPA, 2000a); many of these sensitive groups may not be represented in a healthy worker population. EPA has stated that (USEPA, 1996b):

> "People with decreased liver function, including inefficient glucuronidative mechanism in infants, can have less capacity to metabolize and eliminate PCBs (Calabrese and Sorenson, 1977). Additionally, approximately 5% of nursing infants receive a steroid in human milk that inhibits the activity of glucuronyl transferase, further reducing PCB metabolism and elimination (Calabrese and Sorenson, 1977)."

A study of people exposed through eating contaminated fish (Hovinga et al., 1992) suggests that the PCB mixtures in fish can be more persistent than those to which the workers were exposed. From 1977 to 1985, mean PCB serum levels (quantified using Aroclor 1260 as a reference standard) from 111 Great Lakes fish eaters decreased only slightly from 20.5 to 19.0 ppb (see USEPA, 1996b). Half-life estimates for a mixture can underestimate its long-term persistence (USEPA, 1996b), especially from consumption of fish where changes in PCB blood levels may take longer (Hovinga et al., 1992). This indicates that the rate of decline in the fish eating populations will be slower than that for the workers.

ATSDR's Toxicological Profile (ATSDR, 2000) states that there are no known treatment methods for reducing body burdens of PCBs, concluding that limiting or preventing further exposure appears to be the most practical method for reducing PCB body burdens.

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# WHITE PAPER NO. 14 – wLFRM DEVELOPMENT AND CALIBRATION FOR THE LOWER FOX RIVER/GREEN BAY REMEDIAL INVESTIGATION, FEASIBILITY STUDY, AND PROPOSED REMEDIAL ACTION PLAN

***Review of***

## FOXVIEW DATABASE

***This Document has been Prepared by***
Wisconsin Department of Natural Resources

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# WHITE PAPER NO. 14 – wLFRM DEVELOPMENT AND CALIBRATION FOR THE LOWER FOX RIVER/GREEN BAY REMEDIAL INVESTIGATION, FEASIBILITY STUDY, AND PROPOSED REMEDIAL ACTION PLAN

## ABSTRACT

During the comment period, the Fox River Group (FRG) supplied the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (EPA) with the FoxView Database, as part of their comments to the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a), *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001). The FoxView Database was offered as an alternative to the Fox River Database (FRDB), an interactive web-enabled database developed for the WNDR and EPA to support the RI/FS and subsequent Record of Decision (ROD). This White Paper examines the data provided by the FRG in that database and analyzes the discrepancies between the FoxView Database and the FRDB. It further analyzed what impacts those discrepancies would have on the analyses in the RI/FS.

This White Paper's analyses conclude that the FoxView Database had a large data set not included in the FRDB, but that most of these data did not directly support the RI/FS project and were therefore not relevant for comparison. It was recommended that 20,052 records in FoxView be added to the FRDB along with those record additions currently in progress. After these additions, it was concluded that there would be a less than 1 percent difference in the final comparative record counts, indicating that with respect to the substantive, RI/FS supporting data, there is no effective difference between the FRDB and FoxView databases. This White Paper also examines problems with the FoxView Database including data source discrepancies, missing data, and data redundancies.

## INTRODUCTION

This White Paper reviews the FoxView Database, which was supplied by the FRG with their comments to the RI/FS and Proposed Plan. The goal of the analysis was to determine what data, if any, existed in the FoxView Database but not in the FRDB, and the importance of that data to the RI/FS. In other words, is there data in FoxView that warrants inclusion into the FRDB? Furthermore, if such data was identified, this review attempted to determine why the data is not in the FRDB. The purpose of this White Paper is to provide a general description of the methodology followed and the results obtained.

The FoxView Database ("the Study Area Database") was assembled and submitted by the FRG as part of their comments on the Proposed Plan. According to the Lower Fox River and Green Bay Report: "The Study Area Database is intended to provide Lower Fox

River and Green Bay investigators a common, complete, consistent, and verified resource for research and analysis into environmental trends. Inclusion of water column, sediment and biota samples was emphasized to facilitate analysis of the Study Area for the Fox River Group. Also, emphasis was given to parameters that were most relevant to the needs of the Fox River Group, such as polychlorinated biphenyls (PCBs), solids, and radio-isotope results" (Limno-Tech, 2002, p. 1). FoxView contains nearly 2 million data records.

The FRDB is an interactive, web-enabled database developed by The RETEC Group, Inc. (RETEC) for the WDNR and EPA in support of the RI/FS and *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin, Remedial Investigation and Feasibility Study* (BLRA) (RETEC, 2002c). Development of the FRDB was conducted with two primary goals:

1) The identification and incorporation of available electronic data sets for immediate use in support of BLRA and RI/FS activities and the assessment of those data sets for overall quality and defensibility.

2) The generation of a useable database of Lower Fox River data produced through the identification, acquisition, review (quality assessment of validation), catalog, classification, and archive of all available data pertinent to the Lower Fox River BLRA and RI/FS (EcoChem, 2000, p. 1-1).

The FRDB, as used in support of the October 2001 RI/FS, contains 517, 682 records. Currently, additional data sets are being added to the FRDB which will increase the total number of records by approximately 20,000. (Interested parties may access the FRDB at www.tecinfodex.com/frdb.)

Prior to discussing the details of this analysis, it is imperative that two critical points be clear, one regarding the origins of requirements for inclusion into the FRDB and the other pertaining to the definition of "not in the FRDB."

- The FRDB was originally developed to support the goals of the Lower Fox River RI/FS and to support the subsequent Record of Decision (ROD). While a tremendous amount of data was and is available from studies conducted on the Lower Fox River, not all data supports these basic goals. Data that does not directly support the RI/FS and ROD has consciously been left out of the FRDB. Furthermore, data that does support the RI/FS and ROD is still subject to review prior to inclusion into the FRDB. Historically, data incorporated into the FRDB has been required to meet certain quality assurance/quality control (QA/QC) criteria prior to consideration for inclusion. The primary of these requirements is that the data have undergone a formal, third-party validation, or at a minimum have been reviewed by an independent third party. In lieu of having been reviewed by a third party, the data must have either been generated by a laboratory that had generated contemporary data for samples collected in association with this project (samples that HAVE undergone validation), or must have been delivered with a sufficient level of associated QA/QC data so as to be fully validatable in the future. Data not meeting the above criteria have not, and will not be, included in the FRDB.

- Data sets identified in this White Paper as not being in the FRDB are defined so by the Lower Fox River and Green Bay Database Report Version 6, Appendix A (Limno-Tech, 2002). In the report, the critical benchmark date for inclusion into the FRDB was the 1999 RI/FS submittal of the FRDB. Subsequent to the 1999 iteration of the FRDB, several data sets have been included into the FRDB, including several that the report points out as not in the FRDB. The report does identify some of these data sets as being added to the post-1999 RI/FS version of the database. Data sets that fall into this category will be identified later in this White Paper.

## BACKGROUND AND METHODOLOGY

The impetus for this review was the apparent discrepancy between the FoxView database (1,905,621 records) and the FRDB (517,682 records). This difference of nearly 1.4 million records is what prompted this review. As will be discussed, the vast majority of these 1.4 million records fall into four categories. These categories will be referred to later in this memo when discussing various FoxView data groupings.

- **Category 1.** Data that do not directly support the RI/FS project. Examples would include river flow data, "administrative" data, or non-analytical data such as "Fish, dead (severity)" or "% Cloud Cover."

- **Category 2.** Data that is unable to be verified as meeting a demonstrable level of quality or data that may be redundant within another data set due to origin. This category is primarily represented by data collected under university (or similar) research programs. In these programs (typically), often no definable QA/QC procedures were in place or the data were part of a larger study (e.g. the Green Bay Mass Balance Study [GBMBS]) and are likely to be reported along with data from that study.

- **Category 3.** Data that was collected after the finalization of the 1999 RI/FS FRDB and has already been incorporated into the FRDB or is currently being incorporated into the FRDB. This includes data that has been collected 1999 to the present.

- **Category 4.** Data that has been previously unavailable to WDNR. This data includes the 2000 to present data collected by the FRG and its contractors. The data had not previously been made available to WDNR and consequently is not in the FRDB.

In order to gain an understanding of the information contained within FoxView, a series of simple count queries were conducted on the FoxView database to ascertain how much of what type of information was actually present. These counts were conducted at a relatively high level, but allowed significant portions of FoxView to be segregated out as non-pertinent information. The basic goal of this exercise was to analyze FoxView at a very gross level, to determine if large sections of the database could be grouped into common clusters. As this process proceeded, it was obvious that large sections of the database could be identified as containing data of little or no value for supporting the RI/FS process.

The data in FoxView is organized by "group_name", which is somewhat analogous to the FRDB "analysis_type" field. Initial counts were conducted based upon this field. Table 1 – Breakout of Records in FoxView by Group Name, presents counts of the numbers of records in FoxView as grouped by "group_name" (Count of Total Records). Table 1 also presents the same count, limited to those data sets as being identified as not in the Phase I FRDB (Count of Total Records from Data Sets Identified as NOT Being in the FRDB). Also included in the table is a brief description of the "group_name" field.

Using Table 1 as a first screening, certain database records can be identified as having minimal value with respect to the RI/FS and risk assessment. These would include temperature, flow, administrative, unknown, and other (Tier 1 – data of a non-analytical nature and of little value to the RI/FS). Also included in this group would be physical, general inorganics, dissolved oxygen and oxygen demand, phosphorus, solid, bacteriological, and nitrogen (Tier 2 – data of an analytical nature, but still of little relative value to the RI/FS). Table 2 – Category 1 data, Tiers 1 and 2, presents a summary of those data in FoxView that do not warrant inclusion into the FRDB, as determined on the basis of the type of data under consideration. As is indicated, approximately 1.1 million records in FoxView, but identified as not being in the FRDB may be of little support for use on this project, and consequently do not warrant the effort required for incorporation into the FRDB. Nearly all data summarized in Table 2 falls into Category 1 as defined previously in this White Paper.

## TABLE 1 BREAKOUT OF RECORDS IN FOXVIEW BY GROUP NAME

| Group_name | Count of Total Records | Count of Total Records from Data Sets Identified as NOT Being in the FRDB | Description |
|---|---|---|---|
| Administrative | 105,793 | 102,745 | Non-analytical information such as sample collection locations, analytical instrument type, etc. |
| Bacteriological | 32,630 | 32,630 | Coliform analyses |
| Biological | 27,780 | 21,823 | Chlorophyll, plankton, etc. |
| Dioxins, Furans, Retenes, and Abietanes | 2,359 | 1,604 | |
| Dissolved Oxygen | 54,130 | 53,380 | |
| Flow | 117,766 | 117,455 | |
| General Inorganic | 82,953 | 79,240 | Inorganic “wet” chemistry analyses |
| General Organic | 46,416 | 35,385 | Miscellaneous organic analyses (including VOCs, SVOCs, pesticides, petroleum, wet chemistry) |
| Metal | 88,070 | 84,503 | |
| Miscellaneous | 3,112 | 1,176 | Similar to administrative |
| Nitrogen | 111,749 | 108,105 | Various nitrogen analyses |
| Other | 9,203 | 8,256 | Similar to administrative |
| Oxygen Demand | 72,169 | 72,164 | BOD and COD analyses |
| PCBs | 521,084 | 105,383 | Aroclor, congener, homolog, and total |
| Pesticide | 47,125 | 30,403 | Pesticides and herbicides |
| Phosphorus | 81,624 | 79,933 | Phosphorus/phosphate |
| Physical | 205,332 | 184,127 | Bulk density, dry weight, turbidity, etc. |
| Radiological | 16,627 | 13,343 | |
| Solid | 164,320 | 149,455 | Grain size, total, suspended, dissolved solids |
| Temperature | 115,359 | 110,895 | Air/water temperatures |
| Unknown | 20 | 20 | |
| **Sum** | **1,905,621** | **1,392,025** | |

## TABLE 2 CATEGORY 1 DATA TIERS 1 AND 2*

| Tier | Group_name | Count of Total Records | Count of Total Records from Data Sets Identified as NOT Being in the FRDB | Description |
|---|---|---|---|---|
| 1 | Administrative | 105,793 | 102,745 | Non-analytical information such as sample collection locations, analytical instrument type, etc. |
| 1 | Flow | 117,766 | 117,455 | |
| 1 | Miscellaneous | 3,112 | 1,176 | Similar to administrative |
| 1 | Other | 9,203 | 8,256 | Similar to administrative |
| 1 | Temperature | 115,359 | 110,895 | Air/water temperatures |
| 1 | Unknown | 20 | 20 | |
| | *Sum of Tier 1 Records:* | *351,253* | *340,547* | |
| 2 | Bacteriological | 32,630 | 32,630 | Coliform analyses |
| 2 | Dissolved Oxygen | 54,130 | 53,380 | |
| 2 | General Inorganic | 82,953 | 79,240 | Inorganic “wet” chemistry analyses |
| 2 | Nitrogen | 111,749 | 108,105 | Various nitrogen analyses |
| 2 | Oxygen Demand | 72,169 | 72,164 | BOD and COD analyses |
| 2 | Phosphorus | 81,624 | 79,933 | Phosphorus/phosphate |
| 2 | Physical | 205,332 | 184,127 | Bulk density, dry weight, turbidity, etc. |
| 2 | Solid | 164,320 | 149,455 | Grain size, total, suspended, dissolved solids |
| | *Sum of Tier 2 Records:* | *804,907* | *759,034* | |
| **Sum of Tier 1 and 2 Records:** | | **1,156,160** | **1,099,581** | |

**Note:**
* Tier 1 data is information that is not of an analytical nature, and has little value to the RI/FS. Tier 2 data is more analytical in nature, but is generally still of little relative value to the RI/FS.

The following provides a brief summary of the record distribution within FoxView:

| | |
|---|---|
| Total Records in FoxView | 1,905,621 |
| Records in FoxView Identified as Not Being in FRDB (count from FoxView) | 1,392,025 |
| Records in FoxView with Minimal Value for FRDB (from Table 2) | 1,099,581 |
| Residual Records that Might Warrant Inclusion into FRDB | 292,444 |

As indicated, there are approximately 292,000 records in FoxView, not in FRDB, that would appear to be potentially applicable analytical data records that should be incorporated into the FRDB. Further analysis of these records, however, indicates that only a percentage of these results actually are fit for inclusion into the FRDB. Table 3 – Potentially Important Data, presents a list of data sources, drawn from FoxView that have data potentially pertinent for inclusion into the FRDB. These data sources are all identified within FoxView as not being in the FRDB.

## TABLE 3 POTENTIALLY IMPORTANT DATA

| Source_no | Source | Source Notes | Description | Group_code | Group_name | Count of Total Results |
|---|---|---|---|---|---|---|
| 1101 | STORET | 2 | EarthInfo, Inc. CD-ROM STORET 1996 Region 5:3 States Indiana, Michigan | 8 | Metal | 25,495 |
| | | | | 7 | General organic | 4,061 |
| | | | | 11 | Pesticide | 3,269 |
| | | | | 3 | Biological | 2,442 |
| | | | | 14 | Radiological | 986 |
| | | | | 19 | PCBs | 448 |
| | | | | 20 | Dioxins, furans, retenes, & abietanes | 105 |
| 1102 | STORET | 2 | EarthInfo, Inc. CD ROM STORET 1996 Region 5:4 States Minnesota, Wisconsin | 8 | Metal | 56,316 |
| | | | | 19 | PCBs | 38,894 |
| | | | | 11 | Pesticide | 20,958 |
| | | | | 7 | General organic | 20,098 |
| | | | | 3 | Biological | 14,673 |
| | | | | 14 | Radiological | 1,164 |
| | | | | 20 | Dioxins, furans, retenes, & abietanes | 221 |
| 2401 | BBL | 2 | PCB, PAH, TSP, and temp data for air samples | 7 | General organic | 9 |
| | | | | 19 | PCBs | 9 |
| 2402 | BBL | 2 | PCB congener-specific data for air samples | 19 | PCBs | 1,260 |
| 2403 | BBL | 2 | Total PCB data for snow and rain precipitation composite samples | 19 | PCBs | 38 |
| 2404 | BBL | 2 | Data for total PCBs, PCB transfer from water to air (flux), and physical data for water and air | 19 | PCBs | 362 |
| 3101 | LMMBS | 3 | Congener PCBs, TOC, mercury, moisture data for sediment samples collected in 1994 | 19 | PCBs | 498 |
| | | | | 7 | General organic | 5 |
| | | | | 8 | Metal | 5 |
| 3203 | LMMBS | 3 | Dissolved and particulate congener PCBs, Conventionals, and mercury collected in 1994–1995 in Green Bay | 19 | PCBs | 6,285 |
| | | | | 7 | General organic | 78 |
| | | | | 8 | Metal | 14 |
| 3301 | LMMBS | 3 | Phytoplankton and zooplankton data from water samples in the Fox River, Menominee River and Green Bay | 3 | Biological | 1,173 |
| 4202 | BBL | 3 | Sediment & onshore sediment processing data (10/21/98–12/30/99) – density, grain size, mercury, PCB Aroclors and congeners, TOC | 19 | PCBs | 7,355 |
| | | | | 8 | Metal | 157 |
| | | | | 7 | General organic | 110 |
| 4302 | BBL | 3 | Sediment & onshore sediment processing data (8/16/99–7/18/00) – density, grain size, mercury, PCB Aroclors and congeners, solids, specific gravity, TOC, water content | 19 | PCBs | 11,285 |
| | | | | 7 | General organic | 3,020 |
| | | | | 8 | Metal | 617 |
| 4303 | Ft. James | 4 | Processed sediment, post-dredge sediment, and treated effluent PCBs and physical characteristics from SMU 56/57 during dredging | 19 | PCBs | 714 |
| | | | | 8 | Metal | 24 |
| 4304 | EPA | 4 | Water, sediment, effluent, treatment process PCBs, mercury, TSS, solids, BOD, ammonia, and TP data from SMU 56/57 post-dredge | 19 | PCBs | 53 |
| | | | | 8 | Metal | 43 |
| 4402 | BBL | 3 | 1998–1999 caged fish studies at Deposit N and SMU 56/57 from BBL database LTI.mdb (1/25/01) | 19 | PCBs | 1,877 |
| | | | | 3 | Biological | 128 |
| | | | | 7 | General organic | 128 |

## TABLE 3 POTENTIALLY IMPORTANT DATA

| Source_no | Source | Source Notes | Description | Group_code | Group_name | Count of Total Results |
|---|---|---|---|---|---|---|
| 5301 | BBL | 3 | Water column data (3/10–9/24/98); sediment core and surface sediment data (6/1–8/5/98); and fish and trend fish data (6/2–7/24/98); PCBs, pesticides, organic carbon, solids, mercury, semivolatiles, and metals | 19 | PCBs | 19,018 |
| | | | | 11 | Pesticide | 5,872 |
| | | | | 7 | General organic | 5,059 |
| | | | | 8 | Metal | 1,718 |
| | | | | 3 | Biological | 645 |
| | | | | 14 | Radiological | 462 |
| | | | | 20 | Dioxins, furans, retenes, & abietanes | 61 |
| 5401 | FRG 2000 | 4 | Radioisotope data (cesium-137, lead-210, beryllium-7) for sediment cores collected below De Pere dam and between Lake Winnebago outlet and De Pere dam | 14 | Radiological | 10,731 |
| 5402 | FRG 2000 | 4 | Sediment grab samples for Aroclor PCBs, TOC, TSS and grain size distribution along Fox River | 19 | PCBs | 1,065 |
| | | | | 7 | General organic | 775 |
| 5403 | FRG 2000 | 4 | Water column Aroclor PCBs, congener PCBs (subset of samples), TOC/DOC/POC, TSS results along Fox River and selected tributaries. Water column solids grain size distribution by LALLS method (also known as Malvern analysis) from Heidleberg College | 19 | PCBs | 5,791 |
| | | | | 7 | General organic | 338 |
| | | | | 3 | Biological | 128 |
| 5501 | BBL | 4 | PCB, TOC, physical characteristics measured at 16 stations in inner Green Bay | 19 | PCBs | 240 |
| | | | | 7 | General organic | 150 |
| 6605 | BBL | 2 | Aroclor PCB results for 6 fish species at 8 sites in Lake Michigan (4/95–10/2000) | 3 | Biological | 388 |
| | | | | 7 | General organic | 194 |
| | | | | 19 | PCBs | 194 |
| 6609 | BBL | 3 | Aroclor PCB data for fish samples collected from 4/96 to 8/98 in the Fox River | 3 | Biological | 412 |
| | | | | 7 | General organic | 412 |
| | | | | 19 | PCBs | 312 |
| 6801 | BBL | 2 | Dissolved and particulate PCB data for water samples | 19 | PCBs | 15 |
| 7106 | BBL | 3 | PCB congener, Aroclor, and pesticide data for fish, birds, and a mink in 1996 and 1997 for Green Bay, the Fox River, additional lakes and tributaries, and hatcheries | 19 | PCBs | 6,701 |
| | | | | 3 | Biological | 577 |
| | | | | 20 | Dioxins, furans, retenes, & abietanes | 520 |
| | | | | 7 | General organic | 394 |
| | | | | 11 | Pesticide | 198 |
| 8101 | BBL | 2 | PCBs in sediments | 19 | PCBs | 110 |
| 8202 | BBL | 2 | Total, dissolved, and suspended PCB data and physical data for water samples | 19 | PCBs | 275 |
| | | | | 7 | General organic | 140 |
| 9101 | BBL | 2 | PCB, dioxin, and metals data for sediment samples | 20 | Dioxins, furans, retenes, & abietanes | 221 |
| | | | | 8 | Metal | 78 |
| | | | | 19 | PCBs | 65 |
| | | | | 7 | General organic | 13 |
| 9102 | Exponent | 2 | Brazner & DeVita. PCBs, DDE, and mercury in young-of-the-year littoral fishes from Green Bay, Lake Michigan, Tables 1 & 2. *J. Great Lakes Res.* 24(1):83–92, *Internat. Assoc. Great Lakes Res.*, 1998 | 3 | Biological | 36 |
| | | | | 7 | General organic | 36 |
| | | | | 8 | Metal | 36 |
| | | | | 11 | Pesticide | 36 |
| | | | | 19 | PCBs | 36 |
| 9103 | BBL | 2 | Pesticide, PCB, and PAH biota data | 19 | PCBs | 77 |
| | | | | 11 | Pesticide | 70 |
| | | | | 7 | General organic | 21 |

## TABLE 3 POTENTIALLY IMPORTANT DATA

| Source_no | Source | Source Notes | Description | Group_code | Group_name | Count of Total Results |
|---|---|---|---|---|---|---|
| | | | | 3 | Biological | 7 |
| 9104 | BBL | 2 | PCB, PCDD, PCDF data for eggs and chicks | 20 | Dioxins, furans, retenes, & abietanes | 476 |
| | | | | 19 | PCBs | 140 |
| | | | | 7 | General organic | 128 |
| | | | | 3 | Biological | 28 |
| 9201 | CH2M HILL | 3 | Surficial sediment samples for Aroclor PCBs, TOC, and solids in Little Lake Butte des Morts | 19 | PCBs | 1,988 |
| | | | | 7 | General organic | 141 |
| 9301 | BBL | 2 | Retene, related diterpene hydrocarbons, and PCBs in sediments of the Lower Fox River and Green Bay | 7 | General organic | 75 |
| | | | | 19 | PCBs | 15 |
| 9302 | BBL | 2 | Dissolved and particulate PCB data for water samples | 19 | PCBs | 16 |
| 9401 | BBL | 2 | Sediment PCBs | 19 | PCBs | 216 |
| 9402 | BBL | 2 | Urban area PCB loads from storm drains and catch basins | 19 | PCBs | 10 |

The column in Table 3 identified as "Source Note" is an indicator of the disposition of the data source with respect to inclusion into the FRDB. One of three indicators (2, 3, or 4) has been assigned to each data set to identify why the data set is not in the FRDB, or at least why it is apparently not in the FRDB. These indicators are equivalent to the data categories identified on page 1 of this White Paper.

Data identified as being "Category 2" data will not be incorporated into the FRDB, primarily because these data sets fail the QA/QC requirements set forth for inclusion into the FRDB. Furthermore, these data sets have a great likelihood of containing redundant data that has previously been incorporated into a larger data set.

The data identified as "Category 3" data is either in the FRDB (post-1999) or is currently in the process of being incorporated into the FRDB. "Category 4" data is suitable for incorporation into the FRDB now that it is available to WDNR, assuming it meets the required QA/QC level.

## SUMMARY AND RECOMMENDATIONS

Of the approximately 1.4 million records that FoxView identifies as not in the FRDB, the categorical breakdown is as follows:

| Category Number | Number of Data Sources | Records |
|---|---|---|
| 1 | 38 (all) | 1,288,711 |
| 2 | 16 | 4,830 |
| 3 | 10 | 77,225 |
| 4 | 6 | 20,052 |
| | **Total** | **1,392,025**** |

** When FoxView is queried for all data not in FRDB by group, the total number of records does not match the results of the query when conducted by group subsets. This is likely due to some data redundancy within the database on the key fields used in the query. As the discrepancy is only 1,207 records (0.06 percent of the total database), no effort was expended to determine the exact source of the difference.

As indicated, only 20,052 records (Category 4) remain to be added to the FRDB (not including in-process data additions that account for approximately 20,000 additional records). When these numbers are taken into account and an examination of the total records in FoxView and the FRDB is conducted, the following result is obtained:

| FRDB | | FoxView | |
|---|---|---|---|
| Total FRDB Records | 517,682 | Total FoxView Records | 1,905,621 |
| Approximate Records Yet to be Added (sum of Category 4 data and in-process data) | 40,052 | FoxView Records NOT to be Added to FRDB | 1,351,973 |
| Comparative FRDB Record Count | 557,734 | Comparative FoxView Record Count | 553,648 |

It is recommended that the new data sets (the 20,052 Category 4 data records) be included into the FRDB, along with those record additions currently in progress. Subsequent to completion of this effort, the FRDB will consist of approximately 560,000 records. There will then be a less than 1 percent difference in the final comparative record counts, indicating that with respect to the substantive, RI/FS supporting data, there is no effective difference between the FRDB and FoxView databases.

## REVIEW COMMENTS

During the process of reviewing the apparent data discrepancies between FoxView and the FRDB, several observations were noted that have potential impacts on the accuracy of the comparisons contained herein. These discrepancies are beyond the scope of this task, but are listed here for completeness sake and additional consideration.

### Data Source Discrepancies

There are certain discrepancies between source descriptions as they are defined within FoxView and how they are defined in the Lower Fox River and Green Bay Database Report Version 6.0 (Limno-Tech, 2002). The following provides several examples to illustrate this point.

| Source Number | FoxView Definition (from description field in source table) | Report Definition (from Appendix A) |
|---|---|---|
| 1101 | Earthinfo, Inc. CD-ROM STORET 1996 Region 5:3 States Indiana, Michigan | WI STORET |
| 1102 | Earthinfo, Inc. CD-ROM STORET 1996 Region 5:3 States Minnesota, Wisconsin | MI STORET |

There is confusion between the definitions as to which data source contains data from which state.

### Missing Data in FoxView

While the purpose of this exercise was to look at data in FoxView, but not in the FRDB, it should be noted that certain data are also not in FoxView. This following discussion is by no means comprehensive, but does point out that FoxView is also not comprehensive. It was discovered that a current data set (CH2M HILL data from Little Lake Butte des Morts – FoxView source number 9102) is only partially included in FoxView. While the original data source for this data contains results for 447 environmental samples, FoxView contains results for only 260 samples. A brief analysis of the missing samples shows that the missing data is from the July 2001 sampling event, from sediment samples collected at greater than 100-cm depths, and from the "woodchip" deposits. Furthermore, the Database Report identifies that several small data sets were omitted from inclusion into FoxView.

No attempt was made to verify the overall completeness of the data contained within FoxView. The example cited above was discovered while conducting this analysis. Other similar situations may or may not exist.

### Potential Data Redundancies

Within the data sets incorporated into FoxView, there is a great potential for redundancy between data sets. Much of the information collected by individual researchers in the smaller studies/data sets was used in the larger GBMBS. Additionally, much of the data contained in STORET is data generated under other programs and made available in STORET. Where data from multiple sources has been compiled into a comprehensive data set (STORET, GBMBS), and then that comprehensive data is again mixed with the original source data, the potential is great for redundancies to occur.

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# White Paper No. 15 – FoxSim Model Documentation

***Response to Comments by the Fox River Group***

## FoxSim Model Documentation


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# WHITE PAPER NO. 15 –
# FOXSIM MODEL DOCUMENTATION

## ABSTRACT

As part of the public comments to the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a), *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001), the Fox River Group (FRG) submitted an alternate model entitled FoxSim, which "evaluates the on-going and future natural attenuation of the system" (FRG, 2002). FRG recommended the forecasts created by the FoxSim model be used over those in the *Model Documentation Report for the Lower Fox River and Green Bay* (MDR) (WDNR and RETEC, 2002). This White Paper briefly reviews FRG's modification of the model framework with respect to sediment dynamics and their representation of the physiochemical and biological processes of the Lower Fox River. It further briefly discusses the model results compared to site-specific data that has been collected, the initial polychlorinated biphenyl (PCB) concentrations and sediment thickness presented in the model input files, as well as the framework documentation that has been provided to the Wisconsin Department of Natural Resources (WDNR). Several of the parameters used in the FoxSim model are disputed. This White Paper concludes that the FoxSim model contains many uncertainties in its ability to predict PCB fate and transport in the Lower Fox River system.

## REVIEW

The WDNR has reviewed the FoxSim model documentation provided by the FRG (FRG, 2002) as a part of the comments on RI/FS and the Proposed Plan. To this end, only a brief review of the FRG's extensive modification of the model framework (WASP4/TOXI4) with respect to sediment dynamics and their representation of the physiochemical and biological processes of the Lower Fox River in the FoxSim was possible. Furthermore, the evaluation of some aspects of the model performance could only be accomplished through actually running the model. The following discussions are limited to the brief evaluation of the model results compared to site-specific data that has been collected, the initial PCB concentrations and sediment thickness presented in the model input files, as well as the framework documentation that has been provided to WDNR.

Overall, it appears that the FoxSim model was developed to achieve the objective stated within the model documentation: to "evaluate the on-going and future natural attenuation of the system." A variety of model parameters applied in the FoxSim appear to characterize PCB-contaminated sediment in the Lower Fox River under a less dynamic condition. It may overemphasize sediment deposition in order to achieve the stated objective and hence fewer PCBs are predicted to be transported out of the River system. In addition, it appears that the input files under-represent the current level of PCB contamination in sediment as presented in the output of the Model Evaluation Work

Group as documented in the series of Technical Memoranda jointly developed by the WDNR and FRG modeling consultants.

The United States Geological Survey (USGS) collected water samples at the De Pere dam and near the River mouth for the analyses of PCBs during the 1993 high-flow event. The FRG model documentation did not present the comparison of the model results to the field data collected in 1992 and 1993 at the De Pere dam and the River mouth. The 1993 data was the only data captured under the "high" flow conditions during the model calibration period. If the comparison were made at the both sites, the model would under-predict the concentration by over 30 percent, the model performance goal established by the Model Evaluation Work Group. If the model can not accurately simulate the PCB concentrations in water column under high-flow conditions, it raises doubt as to whether the model is capable of accurately predicting the overall PCB mass transported to Green Bay. Another comparison that could be made that relates to the overall performance of the model is evaluating the FoxSim results in comparison with the data collected at the River mouth for the time period of 1994 and 1995. During this time period, no significant high flow events were recorded. Although the wind-wave-induced sediment resuspension was added into FoxSim, in addition to the flow-induced resuspension, the predicted PCB concentrations in the water column were much lower than the data showed, while the total suspended solids (TSS) matched well. The poor performance of the model in terms of PCB concentrations implies that PCB-laden sediments in the system were not accurately simulated in the model. Potentially, that means the buried PCB-laden sediment was not activated for transport.

Variation of initial concentrations presented in the model could influence the overall attenuation rates of PCBs in surface sediment. As described in the model documentation, the FoxSim model used the 1989–1990 data as the baseline and any data collected after that period were projected backward based on an assumed declining rate with a 10-year half life. This is inconsistent with the procedures agreed to by the WDNR/FRG joint Model Evaluation Work Group and in addition, the application of this interpretation method ignores the fact that the 2000–2001 data presented by the FRG shows an increase of PCB concentrations in surface sediment at some of the locations downstream of the De Pere dam (FRG, 2002). The result is an underestimation of the initial sediment PCB concentrations. Consequently, the results of the long-term simulation of the no-action alternative would be biased low with the surficial sediment PCB concentrations being less under a natural attenuation scenario, while the benefit of active sediment remediation would be reduced.

Another parameter as presented in FoxSim that can have a long-term effect on the model prediction of PCB concentration was the sediment thickness. For upstream of the De Pere dam, the sediment deposits were seemingly arbitrarily presented as 300 cm thick even in the areas where Technical Memoranda developed under the Model Evaluation Work Group and actual field data indicates no soft sediments exist at such depth. For downstream of the De Pere dam, the Sediment Management Units (SMUs) were seemingly arbitrarily limited to 30 cm thick while field data and the Technical Memoranda document contaminated sediment at depths in excess of 300 cm exists in this River stretch. The obvious effect by including deep clean sediments (even non-existing) in the upstream and excluding the highly contaminated sediments downstream, in the long term, for instance 100 years, is that the model projects the transport of clean sediment from upstream and the subsequent deposition of it downstream. The result is the projection would be a demonstration that contaminated sediment in the last 7 miles of the River is buried faster and deeper. Although the precise magnitude of the effect of the vertical sediment thickness on the long-term model simulation can not be evaluated without running the model, based on historical data, as well as that presented by the FRG in their comments, this is clearly not a true representation of PCB-contaminated sediments in the River. In addition, it may well reduce the release of buried PCBs from sediment to the water column and hence being transported to Green Bay.

Additionally, some of the sediment deposition/scour rates simulated by the FoxSim model, as described in the Exhibit 9 (FRG, 2002), were unrealistic. According to the FoxSim model over the 100-year course, some of the areas of the River will be filled with sediments and become upland or island while in other areas a 1-meter deep hole will be created.

In summary, the FoxSim model contains high uncertainties in its ability to predict PCB fate and transport in the Fox River system. The model was constructed with a stated bias to "evaluate the on-going and future natural attenuation of the system." This is accomplished through the model's prediction of deposition of clean sediments and less scour of contaminated sediments, which leads to a prediction of less availability of PCBs to the water column and transport of PCBs within the River, and from the River to Green Bay.

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# White Paper No. 16 – wLFRM Development and Calibration for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision

***Response to a Comments on the***

## Whole Lower Fox River Model

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# ABSTRACT

During the comment period, the Wisconsin Department of Natural Resources (WDNR) and United States Environmental Protection Agency (USEPA) received comments regarding the site-specific water quality model for the Lower Fox River. Commenters took issue with the development and application of the Whole Lower Fox River Model (wLFRM) (WDNR, 2001) conducted for the *Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a). This White Paper presents a response to these comments, in a response/comment format, including overviews of field observations, model development, and model performance assessments.

The wLFRM is the product of more than 10 years of field study and four generations of model development and performance assessment efforts, and included the direct, collaborative involvement of the Fox River Group (FRG) and consultants through the Model Evaluation Workgroup (Workgroup). Development of the wLFRM is consistent with the information developed by the Workgroup in a series of Technical Memoranda (TM). The TM define values for critical model features such as flows, loads, initial conditions, boundary conditions, and sediment transport represent the most detailed description possible of pertinent river conditions using existing data and provided the majority of the information necessary for model development. The development histories of the model framework, IPX 2.7.4, and its application to the Lower Fox River have been extensively documented through numerous reports and peer-reviewed journal publications.

Key findings, supported by wLFRM results, are that PCBs exported to Green Bay must originate from the River sediments, and the rate at which PCB levels decline is relatively slow. Model parameterizations are consistent with observations and published literature. Model results are also consistent with observations and the results of supporting studies such as the PCB trend analysis contained in the Time Trends Report (TMWL, 2002). Given the results of the performance assessment, the wLFRM was judged to be an appropriate tool to evaluate the relative differences between remedial alternatives presented in the RI and the *Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b).

# 1 INTRODUCTION

The selection of a remedy to address polychlorinated biphenyl (PCB) contamination of the Lower Fox River (LFR) and Green Bay (GB) was the end result of an extensive evaluation process consistent with USEPA guidelines for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) projects. The remedy is described in the Proposed Remedial Action Plan (the Proposed Plan) that was issued in October 2001 and the Record of Decision (ROD) for Operable Units 1 and 2 being issued in December 2002 by the USEPA and the WDNR. The Proposed Plan and ROD were developed from information presented in the LFR/GB RI/FS (RETEC, 2002a, 2002b). The RI/FS included information from numerous supporting studies to the help select the remedy. A description of how these supporting studies contributed to the remedy selection process is described in *White Paper No. 9 – Remedial Decision-Making in the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision* (WDNR, 2002a).

Among the supporting studies considered during the remedy selection process were site-specific chemical transport and biota models for the Lower Fox River and Green Bay. One of those site-specific models is the “whole” Lower Fox River model (wLFRM). The wLFRM is the result of numerous assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. The wLFRM was developed to examine the movement and distribution (transport and fate) of PCBs in the Lower Fox River based on consideration of the observed physicochemical properties of the chemical, PCB concentration trends in water and sediment, and observed interactions between the water column and sediment bed such as resuspension and net burial (WDNR, 2001a).

This White Paper addresses issues concerning wLFRM development and calibration for the LFR/GB RI/FS, the Proposed Plan, and ROD. Development of the wLFRM was guided by comparisons to field observations. The usefulness of the wLFRM was determined by comparing model results to observations conditions. In order to understand the development and calibration of wLFRM, it is therefore necessary to first understand observed conditions for the River. A summary of observed conditions for the River is presented in Section 2 of this White Paper. Model development and calibration are then guided by this understanding of the observed conditions. A summary of model development and calibration is presented in Section 3. Comparisons between model results and observed conditions are then summarized in Section 4. Discussions of wLFRM performance in light of comments received during the RI/FS public comment period are presented in Section 5. Finally, conclusions regarding wLFRM performance and usefulness in the RI/FS are presented in Section 6.

# 2 OBSERVED CONDITIONS IN THE LOWER FOX RIVER

PCBs are the main contaminant of human health and ecological concern in the Lower Fox River and Green Bay. PCBs are a series of chlorinated organic chemicals that are hydrophobic, readily associate with sediments and fat tissues (lipids), and are believed to cause cancer, birth defects, and impair immune systems. PCBs were discharged to the River during the manufacture and recycling of carbonless copy paper. Approximately 317,000 kg of PCBs were discharged to the River between 1954 and 1997 (WDNR, 1999a). Present PCB levels exceed water quality standards and contaminate fish to unsafe levels. As a result of this extensive contamination, fish consumption advisories for the River have been in place since 1976.

The wLFRM was developed to examine the transport and fate of PCBs in the Lower Fox River and was calibrated using data collected as part of the USEPA 1989-1990 Green Bay Mass Balance Study (GBMBS), the 1994-1995 Lake Michigan Mass Balance Study (LMMBS), and other field studies over the period 1989 to 1995 (WDNR, 2001a). The 1989 to 1995 timeframe is the period over which the River was sampled in the most extensive and comprehensive manner. Additional studies completed since 1995 were also considered. Field data define observed conditions and trends. Model performance is assessed by comparing how closely model results compare to observed conditions and trends. For the Lower Fox River, field data allow the following conditions and trends to be defined:

1. Observed PCB trends in water;
2. Observed PCB trends in surface sediment;
3. Observed sediment bed elevations changes;
4. Rates of net sediment accumulation; and
5. Depths and rates of sediment mixing.

An overview of Lower Fox River conditions defined by field observations follows. More full descriptions of observed conditions for the River are presented in the reports *Development and Application of a PCB Transport Model for the Lower Fox River* (WDNR, 2001a) and Technical Memorandum 3a (WDNR, 2001b).

## 2.1 OBSERVED SPATIAL AND TEMPORAL PCB TRENDS IN WATER

Observed spatial trends in Lower Fox River water column PCB concentrations were determined by examining PCB levels measured at different location from Lake Winnebago to the River mouth. The data show that PCB concentrations go from essentially non-detectable levels at Lake Winnebago, to levels in Little Lake Butte des Morts that exceed water quality standards, and progressively increase with location downstream. The most complete set of observations is for the period 1989 to 1995 and includes samples collected at up to six locations along the River: (1) Lake Winnebago (the dams at Neenah and Menasha at the head of the River), (2) Appleton, (3) Kaukauna, (4) Little Rapids, (5) De Pere, and (6) the River mouth at Green Bay. During the 1989-1990 GBMBS, samples were collected at all six locations at a number of times. Data for the Lake Winnebago, Appleton, De Pere and River mouth sites are presented in Figure 2-1. Given that all external PCB inputs (i.e. wastewater discharges) to the River are controlled, the data also demonstrate that residual PCB releases from River sediments are the present-day source of PCBs to the water column.

Observed temporal trends in Lower Fox River water column PCB concentrations were determined by examining PCB levels measured over time. Both seasonal and year-to-year trends were examined. The data show that consistent seasonal trends exist and that no significant year-to-year trend exists. Over time across all locations, there is a consistent trend of low PCB levels during winter months and higher levels during summer months. Over time, the most complete set of observations were collected at the River mouth. Regression analyses over the period 1989 to 1995 suggest that differences in water column PCB levels over time are not statistically significant.[1, 2] Data from the River mouth site over time are presented in Figure 2-2.

In summary, three conclusions may be drawn from these data: (1) ongoing PCB transport from sediments causes water column PCB levels to increase from essentially zero at the upstream limit of the River to levels that greatly exceed water quality standards throughout the River; (2) seasonal patterns of low PCB levels during winter months and higher levels during summer months exist; and (3) water column PCB concentration changes over time are expected to be slow or near zero.

## 2.2 OBSERVED SPATIAL AND TEMPORAL PCB TRENDS IN SURFACE SEDIMENT

Observed spatial and temporal trends in Lower Fox River surface sediment PCB concentrations were determined by examining PCB levels measured at all locations between Lake Winnebago to the River mouth by position (distance from Lake Winnebago) and year of sample collection. Sediment PCB concentrations have been measured at approximately 850 horizontal locations and at many different depth intervals throughout the Lower Fox River. The most complete set of observations is for the period 1989 to 1995 with additional samples collected at further locations in more recent years. An overview of these data is presented in Technical Memorandum 2e (TM2e) (WDNR, 1999b). Accurate quantification of spatial and temporal PCB concentration trends in Lower Fox River sediments is complex. None of the data collection efforts were

1 Determinations of water column PCB trends are very difficult. PCB concentrations are affected by a wide range of physical factors including, river flow, suspended solids concentrations, temperature, seiching between the River and Bay, and also by differences in sample collection and analytical protocols over time. Even neglecting these confounding factors, any trend that may be inferred from these data is weak, explaining almost none of the data variability (very low $r^2$), not statistically significant ($p > 0.05$), and has a wide 95 percent confidence interval that ranges from a slight decreasing trend to a slight increasing trend over time.

2 Additional water column PCB samples were collected at the River mouth in 1997. Unfortunately, these data are not directly useful for estimating year-to-year trends because those sampling efforts used very different sample collection and analytical protocols. Without a means to account for the potentially large biases that can occur as a result of the different protocols, the 1997 data cannot be directly used for a trend assessment.

specifically designed to estimate PCB concentration trends over time. In addition to being collected at different horizontal and vertical intervals and at different times, cores from each sampling effort were generally analyzed using different analytical techniques and quantitation standards. The differences introduced as a result of spatial heterogeneity, temporal variability, and analytical bias confounds identification of possible trends. Consequently, the nature and influence of these confounding factors must be considered when estimating the scale of possible PCB trends.

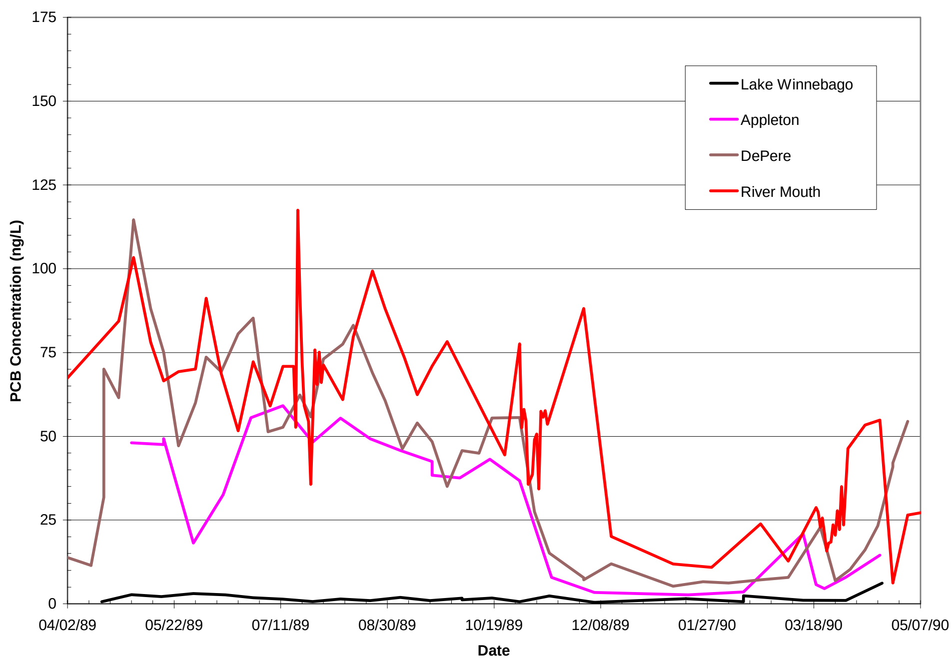



**FIGURE 2-1 WATER COLUMN PCB CONCENTRATION FROM LAKE WINNEBAGO TO THE RIVER MOUTH**

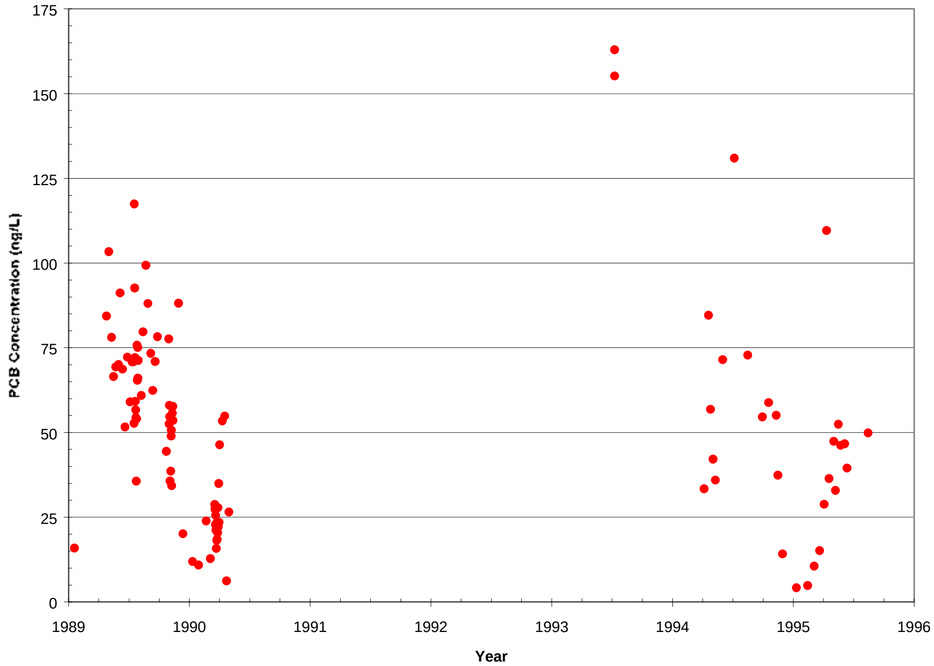


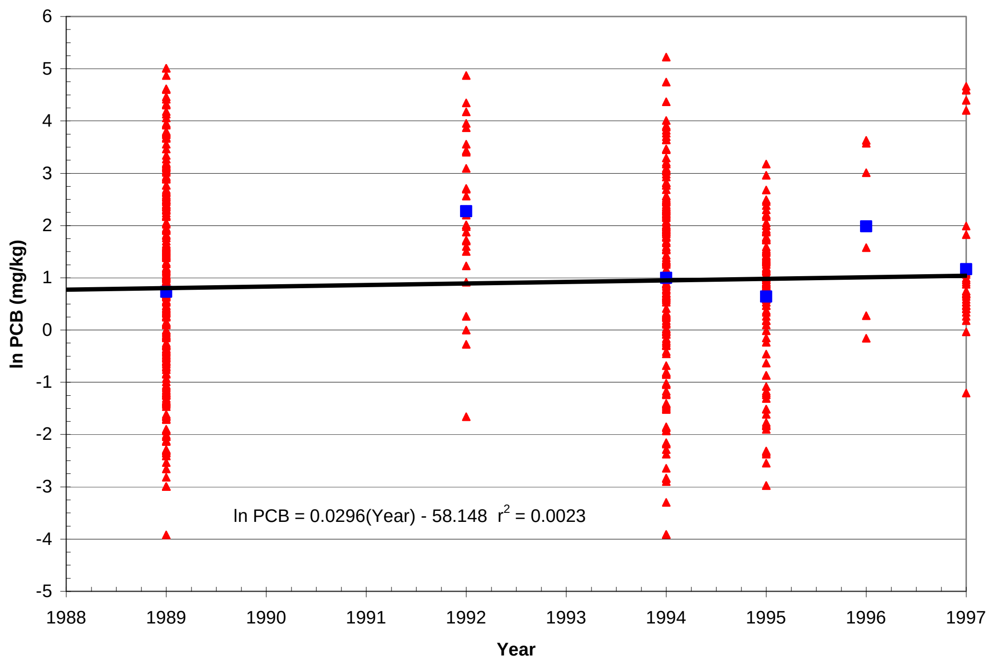

**FIGURE 2-2 WATER COLUMN PCB CONCENTRATIONS AT THE RIVER MOUTH: 1989-1995**

Considering the surface sediments (0-10 cm) of the entire River, as well as individual River reaches, the potential ranges of spatial and temporal PCB concentrations trends were examined. These results are presented in Figures 2-3 and 2-4 and Table 2-1. The results suggest that PCB concentrations generally decrease with distance downstream of Lake Winnebago. When expressed as an apparent annual rate of change, across the entire River PCB concentrations in the upper 10 cm of sediment appear to be increasing over time at an average rate of approximately 5 percent per year. However, the results also suggest that some apparent concentration increases over time may reflect the spatial heterogeneity of sediment PCB concentrations. As just one example of spatial heterogeneity, consider that surface sediment PCB concentrations in samples collected during 2001 from Little Lake Butte des Morts were higher than reported in any prior study. These data could be taken to suggest that PCB levels increased over time. However, given that there are no external PCB sources to the River, it is more likely that concentration differences over time represent spatial heterogeneity. Further, the trend analysis results also suggest that the year of sample collection describes very little of the variability of sediment PCB concentrations. Overall, the trend analyses indicate that PCB concentrations in any reach may increase, decrease, or stay the same over time. Further description of the trend analyses is presented in Appendix B of WDNR (2001a). Additional analyses based on different assumptions are presented by TMWL (2002).

In summary, four conclusions may be drawn from these data: (1) a spatial trend of generally decreasing sediment PCB concentration with distance from Lake Winnebago exists; (2) apparent PCB concentration changes over time may reflect the spatial heterogeneity of PCBs in the sediments; (3) at any individual location, sediment PCB concentrations may increase, decrease, or stay the same over time; and (4) the overall rate at which surface sediment PCB concentrations change over time is slow.

## TABLE 2-1 INFERRED SURFACE SEDIMENT (0-10 CM) PCB CONCENTRATION TRENDS OVER TIME

| Reach[3] | Inferred Rate of Change (%/year) | Rate at Lower 95% CL[4] (%/year) | Rate at Upper 95% CL (%/year) | Notes |
|---|---|---|---|---|
| 1 | -22.8<br>(-16.0 to -29.7) | -29.2<br>(-20.4 to -37.9) | -15.9<br>(-11.1 to -20.7) | Apparent trends may be attributable to shifts in sampling sites over time. |
| 2 | +41.8<br>(+29.3 to +54.4) | +22.2<br>(+15.4 to +28.9) | +64.4<br>(+45.2 to +84.0) | |
| 3 | -8.1<br>(-5.7 to -10.6) | -19.6<br>(-13.7 to -25.4) | +4.9<br>(+3.4 to+6.4) | Apparent trends may not be significantly different from zero. |
| 4 | 0 | -6.6<br>(-4.6 to -8.5) | +7.0<br>(+4.9 to +9.1) | |
| All | +5.6<br>(+3.9 to +7.3) | +0.8<br>(+0.6 to +1.1) | +10.6<br>(+7.4 to +13.8) | Significance of apparent trend unclear. Sampling efforts varied spatially and over time. |




## FIGURE 2-3 SURFACE SEDIMENT PCB CONCENTRATION TREND OVER TIME: ALL REACHES (0-10 CM)

3 River reaches are defined in Table 3-2 of this report.

4 Confidence limit.

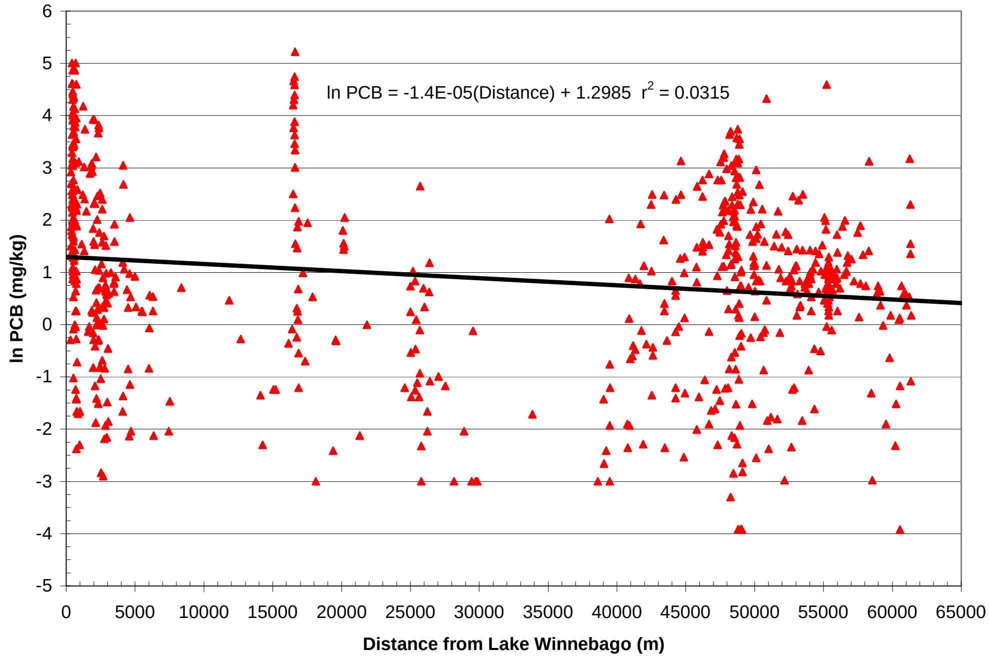



**FIGURE 2-4 SURFACE SEDIMENT PCB CONCENTRATION TREND OVER SPACE: ALL REACHES (0-10 CM)**

## 2.3 OBSERVED SEDIMENT BED ELEVATION CHANGES

Observed sediment bed elevation changes in Lower Fox River were determined by examining hydrographic survey results. These results indicate that the sediment bed of the Lower Fox River is not necessarily a stable environment for PCBs. At many locations large gross sediment bed elevations increases and decrease were observed over time, while over broad areas much smaller net changes in bed elevation were observed. As a result of bed elevation changes, the profile of PCBs in the sediment column may be altered. Where bed elevations decrease, the changing position of sediment-water interface may expose PCBs once located deeper in the sediments.

Sediment bed elevation dynamics were examined as part of Technical Memorandum 2g (TM2g) (WDNR, 1999c). In that effort, hydrographic surveys of the River conducted by the USACE, USEPA, and USGS were reviewed to describe sediment bed elevations at selected locations along the River for the period 1977 to 1998. Most of these data were collected downstream of the De Pere dam in the last 15 kilometers (seven miles) of the River. Sediment bed elevation changes are observed in both cross-channel and downstream profiles. Short-term (annual and sub-annual) average net sediment bed elevation changes at individual locations range from a decrease of 28 cm to an increase of 36 cm. Long-term (several years) average net elevation changes at individual locations range from a decrease of more than 100 cm to an increase of nearly 45 cm. These average changes are well-supported by sediment volume calculations performed by the USACE as part of hydrographic surveys as well as results of the USGS surveys performed at intermediate time scales (8 months to 45 months). Average bed elevation changes over time for the selected long-term (USACE) cross-channel range lines presented in TM2g (WDNR, 1999c) range from -5.5 to + 5.4 cm/year (see Table 7 of TM2g). These results document the dramatic changes in sediment bed elevations that can occur as the bed of the Lower Fox River is continuously reshaped by the wide range of flows and loads the River experiences.

As a follow-up to TM2g, data for recent hydrographic surveys completed by the USACE were further examined to determine the extent of bed elevation changes. Data for the 1997, 1998, and 1999 surveys were available in a form that permitted calculation of bed elevation changes for all locations surveyed (rather than only at selected locations as shown in TM2g). These results were examined for the portion of the navigation channel from the De Pere to Fort James (Georgia Pacific) turning basins. This portion of the channel has not been dredged since the 1960s so changes in bed elevations reflect the natural channel-forming dynamics of the River. Survey results detailing sediment bed elevation changes between the 1997 and 1999 surveys are presented in Figures 2-5. These data were collected at transect lines positioned every 30 meters (100 feet) along the channel. As reported by the USACE, these surveys provide more than 25,000 individual bed elevation observations for this portion of the channel. Note that a net sediment gain or loss ("burial") rate for a given time period may be estimated from sediment bed elevation change data as the net elevation change over the time between surveys. A summary of results is presented in Table 2-2. These results again document the dramatic changes in sediment bed elevations that can occur as the bed of the Lower Fox River is continuously reshaped by the flows and loads the River experiences. This is further documented by long-term bed elevation data collected by the USACE. Long-term sediment bed elevation profiles along the navigation channel over the period 1977 to 1998 are presented in Figure 2-6. These profiles show that large changes in sediment bed elevation can occur.

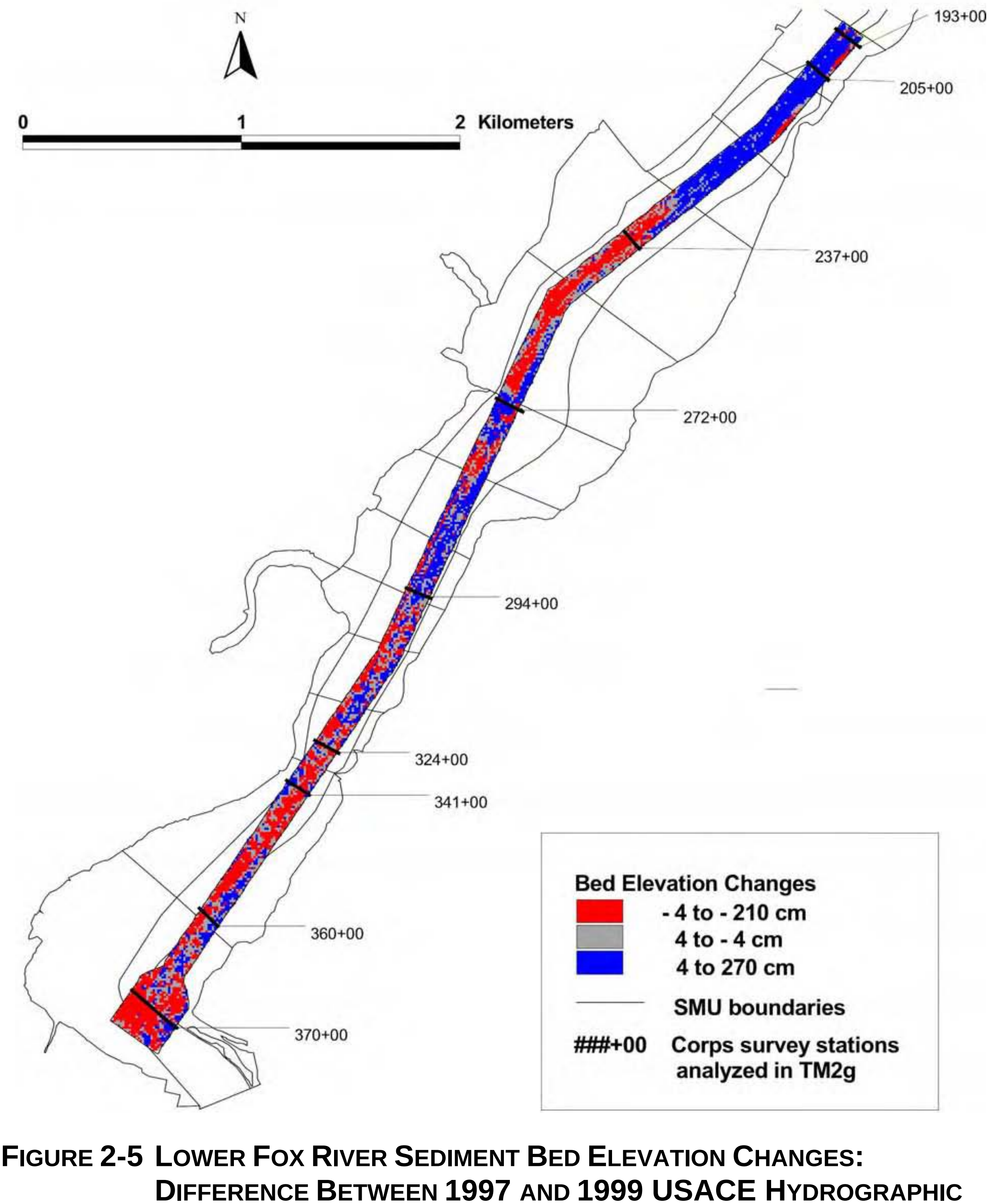



**FIGURE 2-5 LOWER FOX RIVER SEDIMENT BED ELEVATION CHANGES: DIFFERENCE BETWEEN 1997 AND 1999 USACE HYDROGRAPHIC SURVEY RESULTS**

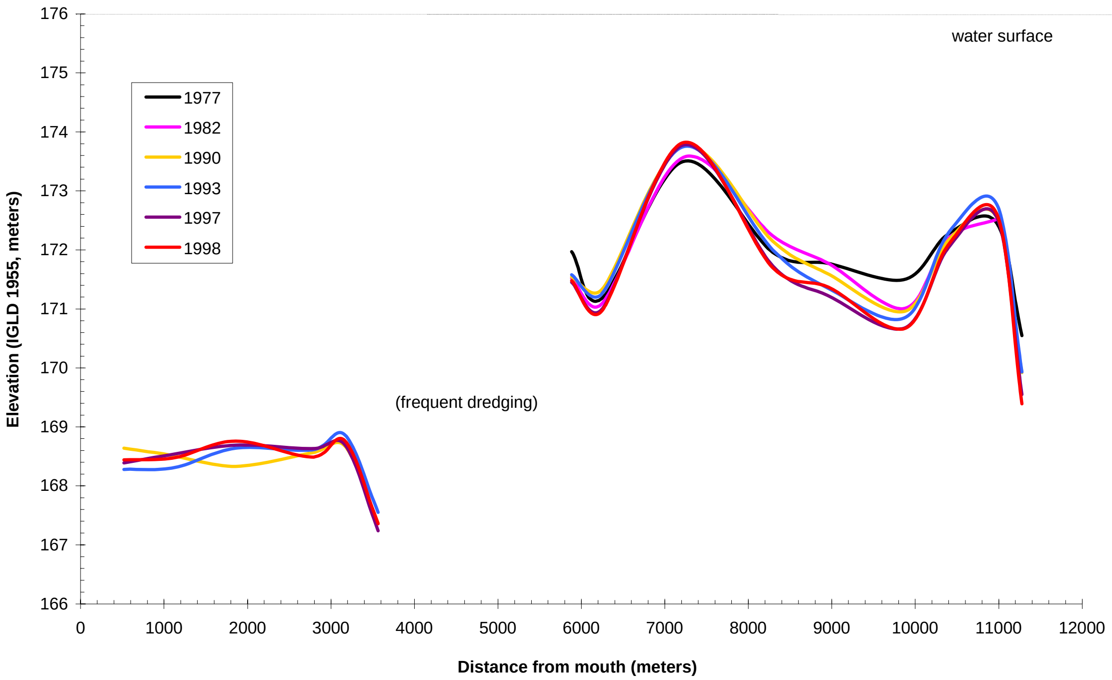



**FIGURE 2-6 LOWER FOX RIVER SEDIMENT BED ELEVATION PROFILES: 1977-1998**

**TABLE 2-2 LOWER FOX RIVER SEDIMENT BED ELEVATION CHANGES, DE PERE TO FORT JAMES (GEORGIA PACIFIC) TURNING BASINS: 1997-1999**

| Survey Years | Minimum (Maximum decrease at a single point) (cm) | Maximum (Maximum increase at a single point) (cm) | Mean (Average change over all points) (cm) | Volume Change (Cumulative over all points) ($m^3$) |
|---|---|---|---|---|
| 97-98 | - 174 | + 131 | + 6.3 | + 43,717 |
| 98-99 | - 115 | + 270 | - 5.6 | - 38,986 |
| 97-99 | - 209 | + 226 | + 0.7 | + 4,981 |

These results document that (at least for the 1997-1999 surveys) gross changes in bed elevation at any individual point can be large and differ widely from the net change in elevation in terms of both magnitude and direction. Additionally, a recent study also suggests that portions of the sediment bed downstream of the De Pere dam may be subjected to increased erosion (observed as decreased sediment bed elevations) in response to declining water levels in Green Bay/Lake Michigan. Also note that these data also permit estimation of net rates of sediment accumulation in the River. Net sediment accumulation rates are presented in Section 2.4.

It should be noted that the overall accuracy of the USACE hydrographic surveys was extensively examined. As described by WDNR (1999b, 2001a), the majority of the bed elevation data used for these studies was collected by the USACE as part of Class I surveys. The accuracy of these surveys was confirmed by field tests of the actual combined errors (equipment and procedural) of measurements. Data collected at the Sediment Management Unit (SMU) 56/57 demonstration site in August 1999 indicate that the combined vertical accuracy achieved by the USACE Kewaunee Office was approximately ±4 cm (WDNR, 1999d).

Finally, it is worth noting that in terms of the dynamics of sediment bed elevation changes, the Lower Fox River is not unique. Similar ranges of bed elevation changes have been observed in the Sheboygan River (Wisconsin) (WDNR, 2000a). A recent study of bed mobility in the Sacramento River (California) also demonstrates that the bed of a river can be a very dynamic environment (Dinehart, 2002). In that study, the upper 30 cm of the sediment bed was typically found to be mobile (bedform transport) and moved downstream at rates that ranged from 0.43 to 2.01 m/day (Dinehart, 2002).

In summary, three conclusions may be drawn from these data: (1) large gross increases and decreases in sediment bed elevation can occur at any individual location over time; (2) for broad areas of the River, the net change in sediment bed elevation over time is generally much smaller than the gross changes at individual points; and (3) the sediment bed of the Lower Fox River is not necessarily a stable environment for PCBs because decreases in bed elevation at any point can expose PCBs that were once deeper in the sediment column.

## 2.4 Rates of Net Sediment Accumulation

The net rate of sediment accumulation in the Lower Fox River is small. As a consequence, the rate at which PCBs in the sediment bed become isolated from the environment is slow. Rates of net sediment accumulation (net burial rates) were examined by WDNR (2001a). As part of those efforts, net sediment accumulation rates were estimated from a range of information including: (1) sediment bed elevation surveys over time; (2) average depths of maximum PCB concentrations in the sediments and the time since peak discharge; and (3) sediment trap efficiencies and annual sediment budgets. Brief descriptions of these net burial rate estimates follow. More complete descriptions are presented by WDNR (2001a).

The average sediment bed elevation change over a specific time period was used to estimate a net rate of sediment accumulation. From results of the 1997-1999 USACE hydrographic surveys of the River navigation channel between the De Pere and Fort James (Georgia Pacific) turning basins. As noted in Section 2.3, a 0.7 cm increase in average sediment bed elevation occurred over a two-year period in this section of the River. This corresponds to an estimated net burial rate of +0.35 cm/year.

The average depth of maximum PCB concentrations in the sediments column and the time since peak discharge were used to estimate a net rate of sediment accumulation. For samples collected from the River in 1995 (between De Pere and Green Bay), the average depth to maximum PCB concentrations was 24 to 56 cm below the sediment-water interface. Based on TM2d (WDNR, 1999a), the year of peak PCB discharges to the River was 1969. As described in TM2d, note that most PCB discharges to the River occurred prior to implementation of present-day wastewater treatment practices. During the period of peak PCB discharges, loads of point source solids that delivered PCBs to the River were much larger than contemporary loads. Further, the settling characteristics of the particles comprising those loads were substantially different (i.e. untreated versus treated wastes). After accounting for the changing magnitude and characteristics of point source solids over time, the inferred average net burial rate for the 1989 to 1995 period is 0.2 to 1.4 cm/year (WDNR, 2001b).

Sediment trap efficiencies and annual sediment budgets for the River were used to estimate a net rate of sediment accumulation. Using the methods described by Brune (1953) and Dendy (1974), sediment trap efficiencies for the River were estimated to be roughly 10 to 20 percent. Given the total external load of solids to the River, these sediment trap efficiency estimates were used to infer a net burial rate. As estimated from the results of TM2a (FWB2000, 1998), TM2c (LTI, 1999b), TM2d (WDNR, 1999a), and TM3a (WDNR, 2001a), the average total solids load to the Lower Fox River for the period 1989 to 1995 was approximately 146,000 MT/year. With this total load and an overall sediment trap efficiency of roughly 10-20 percent, approximately 14,600-29,200 MT of sediment would be added to the sediment bed annually. Given the total surface area of sediments ($1.19 \times 107\ m^2$) and the average bulk density of sediments in those areas ($5.96 \times 106\ g/m^3$), this corresponds to a net burial rate of approximately 0.21 to 0.42 cm/year.

Note that each of these different methods yields similar net burial rate estimates. Differences in average bed elevation changes over time is the best method for estimating burial rates because it is based on direct observations of the displacement of the sediment-water interface over a given time period. Estimates by other methods are more uncertain. Nonetheless, the 0.2 to 1.4 cm/year rate estimated from the depth of PCB occurrence and the 0.21 to 0.42 cm/year estimated from sediment trap efficiencies are nonetheless in close agreement with the 0.35 cm/yr estimate from bed elevation surveys.

In summary, two conclusions may be drawn from these data: (1) as determined by different approaches, the net rate of sediment accumulation (net burial) in the Lower Fox River is small; and (2) the corresponding rate at which PCBs in the sediment bed become isolated from the environment due to net burial is slow.

## 2.5 Depths and Rates of Sediment Mixing

Near the sediment-water interface, disturbances of sediments by bioturbation and other events can mix particles (and particle-associated contaminants) within the sediment column. Mixing can cause PCB initially present deeper in the sediment column to return to the sediment surface. The depth to which sediments mix over time in the Lower Fox River is variable. For biological processes, mixing can occur in the top 10 cm of sediment. Other sediment disturbances may mix sediments to much greater depths (as much as 200 cm). Similarly, the rate at which sediments mix is also variable. Depths and rates of sediment mixing in the River were estimated from a range of information including: (1) benthic sediment re-working rates and abundance data; (2) radioisotope data; and (3) sediment bed elevation change data.

Bioturbation can extensively mix sediments (Lee and Schwartz, 1980; McCall and Tevesz, 1982). The depth through which mixing may occur depends on a variety of conditions (pH, dissolved oxygen, temperature, etc.) and the types and abundances (densities) of organisms involved. Benthic community surveys of Lower Fox River sediments indicate that the predominant species of benthic organisms are chironomids and oligochaetes with abundances that range from 500 to 15,000 individuals/$m^2$ and an average density of approximately 4,500 individuals/$m^2$ (IPS, 1993a; IPS, 1993b; IPS 2000; WDNR, 1996). Investigations of Great Lakes sediments found that these types of benthic organisms can re-work (mix) sediments to depths of 10 to 20 cm and at rates of $0.33 \times 10^{-5}$ to $3.66 \times 10^{-5}$ cm/day/$m^2$/organism (Matisoff et al. 1999; Matisof and Wang, 2000). This corresponds to sediment mixing rates ranging from $1.72 \times 10^{-10}$ to $3.81 \times 10^{-9}$ $m^2$/s.

Short-term radioisotope tracer studies of Lower Fox River sediments confirm that extensive mixing occurs in the upper sediments. Fitzgerald et al. (2001) examined Beryllium-7 (Be-7) profiles in Lower Fox River sediments. Be-7 is a naturally occurring, short-lived (53-day half-life) radioisotope formed in the upper atmosphere that can be used to determine depths and rates of surface sediment mixing for timeframes between six months to less than one year. Fitzgerald et al. (2001) reported that Be-7 occurred at depths of 5-10 cm in the sediment column. This corresponds to a minimum effective mixing rate of $7.92 \times 10^{-11}$ to $6.34 \times 10^{-10}$ $m^2$/s (5 cm/yr to ~10 cm/0.5 yr). Note that the mixing rate computed from Be-7 observations is similar (within a factor of ~2) to biological mixing rates. It is worth noting on one occasion that detectable Be-7 concentrations were observed in the deepest sample collected. This indicates that for Be-7 both the sediment mixing depth and rate can be greater than the estimated value.

Other processes such as bed elevation changes due to flow events, density currents, and sediment slumping can also disturb and mix sediments. As described in TM2g (WDNR, 1999c) and follow-up efforts (WDNR, 2001a), sediment bed elevations in the Lower Fox River are very dynamic. Over monthly to annual times scales, sediment bed elevations have been observed to regularly fluctuate between 10 to 30 cm. Larger fluctuations of approximately 200 cm have also been recorded over annual time scales. Over broad areas, the net change in bed elevation is very small. This means that at each location where a large decrease in bed elevation occurs, there is typically a nearby location with a correspondingly large increase in elevation. Consequently, within the same general area there is a pattern of mixing where particles and contaminants located deeper within the sediment column can return to the sediment surface and materials initially at the surface are buried until the next disturbance occurs. The mixing depths and rates of such disturbances are highly variable. As noted above, sediment disturbance (mixing) depths of 10 to 30 cm are regularly observed over time frames of roughly one year. This corresponds to mixing rates that range from $3.17 \times 10^{-10}$ to $2.85 \times 10^{-9}$ $m^2$/s.

Long-term radioisotope tracer studies of Lower Fox River sediments confirm that mixing occurs to deeper depths in the sediment column. Steuer et al. (1995) examined Cesium-137 (Cs-137) profiles in Lower Fox River sediments. Cs-137 is a man-made (originating from atmospheric nuclear weapons tests), long-lived (30-year half-life) radioisotope that can be used to estimate depths and rates of sediment mixing for timeframes over the last 40 to 50 years. Steuer et al. (1995) reported that Cs-137 profiles were not interpretable at 15 of 24 locations sampled. At those locations, samples were collected at depths up to 40 cm below the sediment surface. This corresponds to an upper bound for mixing rates at disturbed locations of $1.88 \times 10^{-10}$ $m^2/s$.[5] Note that the mixing rate computed from Cs-137 observations is similar (within a factor of ~2) to mixing rates inferred from bed elevation changes.

It is worth noting that sediment disturbances or mixing depths are not uniform throughout the River. However, even at locations where disturbances are less extensive and the sediments preserve interpretable radiotracer profiles, sediment near the sediment-water interface mix over time. LTI (2002) examined Cs-137 profiles in Lower Fox River sediments. LTI (2002) reported that several locations were "not consistently depositional" (i.e. subject to mixing and erosion). Overall, LTI (2002) reported that sediment mixing depths at undisturbed locations ranged from 1 to 20 cm and with an average mixing depth of 6 to 12 cm. Again, these finding are consistent with other estimates of mixing depth.

In summary, four conclusions may be drawn from these data: (1) the typical depths to which sediment mix over time are variable and ranges from 5 to 30 cm; and (2) the maximum depths to which sediment are disturbed over time may be as large as 200 cm; (3) even at locations subject to fewer disturbances, average mixing depths from 6 to 12 cm and maximum mixing depths of 20 cm have been observed; and (4) mixing rates on the order of $1.0 \times 10^{-10}$ $m^2/s$ occur in the River.

## 2.6 SUMMARY OF FIELD OBSERVATIONS

The period 1989 to 1995 is the timeframe over which the Lower Fox River was sampled in the most extensive and comprehensive manner. Based on field studies completed over this period, as well as additional studies completed since 1995, observed conditions such as PCB trends in water and surface sediment, sediment bed elevation changes, rates of net sediment accumulation, and depths and rates of sediment mixing specific to Lower Fox River conditions were defined.

Analyses of PCB concentration trends in water indicate that ongoing PCB transport from sediments causes water column PCB levels to increase from essentially zero at the upstream limit of the River to levels that greatly exceed water quality standards throughout the River. Seasonal patterns of low PCB levels during winter months and higher level during summer months exist. However, year-to-year differences in water column PCB levels are not statistically significant, suggesting that concentration changes over time are expected to be slow or near zero.

Analyses of PCB concentration trends in surface sediments indicate that across the entire River a spatial trend of generally decreasing sediment PCB concentrations with distance from Lake Winnebago exists. The trend analyses further indicate that surface sediment PCB concentrations in any reach may increase, decrease, or stay the same over time.

[5] This computation is based on the assumption that complete sediment disturbance occurred to the maximum depth of the samples (~40 cm) over the maximum timeframe for disturbance. The maximum timeframe for disturbance was 27 years as computed as difference between the year of sample collection (1990) and the year of peak Cs-137 fallout (1963).

Across the whole River, the overall rate at which surface sediment PCB concentrations change over time is expected to be slow.

Analyses of sediment bed elevation changes with the Lower Fox River indicate that large gross increases and decreases in bed elevation can occur at any individual location over time. However, for broad areas of the River, the net change in bed elevation over time is generally much smaller than the gross changes at individual points. The large difference between gross and net bed elevation changes indicate that the sediment bed of the River is not necessarily a stable environment for PCBs because decreases in bed elevation at any point can expose PCBs that were once deeper in the sediment column.

Analyses of net sediment accumulation (net burial) rates indicate that recent net burial rates for the Lower Fox River are small. Based on a variety of methods, net burial rates were estimated to be approximately 0.3 cm/yr. As a result of low net burial, the corresponding rate at which PCBs in the sediment bed become isolated from the environment expected to is slow.

Analyses of depths and rates of sediment mixing in the Lower Fox River indicate extensive mixing of sediment can occur and can at time affect the sediment bed to significant depths. Typical depths to which sediments mix over time are variable and range from 5 to 30 cm. The maximum depths to which sediment are disturbed over time may be as large as 200 cm. Even at locations subject to fewer disturbances, average mixing depths from 6 to 12 cm and maximum mixing depths of 20 cm have been observed. Average sediment mixing rates on the order of $1.0 \times 10^{-10}$ $m^2/s$ are estimated to occur in the River.

# 3 MODEL DEVELOPMENT HISTORY, ORGANIZATION, AND CALIBRATION

## 3.1 MODEL DEVELOPMENT HISTORY

The Lower Fox River/Green Bay ecosystem was extensively studied as part of the 1989-90 GBMBS (USEPA 1989; USEPA 1992a,b). As part of the GBMBS, a suite of water quality models describing PCB transport in the Lower Fox River and Green Bay were developed. Two of those models described PCB transport in upstream and downstream portions of the Lower Fox River (Velleux and Endicott, 1994; Steuer et al 1995). Since the end of the GBMBS, efforts to examine and assess the performance of Lower Fox River water quality models have continued. Four generations of model development have been completed. The models calibrated to GBMBS conditions represent the first generation of model development for the River (Steuer et al. 1995; Velleux and Endicott, 1994). The extension of those models to forecast future water quality trends was the second generation of development (Velleux et al. 1995, Velleux et al. 1996). The models used to conduct a post-audit analysis of model performance represent the third generation of development (WDNR, 1997). The model developed as part of RI/FS efforts is the result of continued assessments of Lower Fox River water quality model performance and is the fourth generation of model development. To distinguish it from prior generations of development, this fourth generation model is identified as the “whole” Lower Fox River model (wLFRM).

Development of the wLFRM was based on the results of a 1997 agreement and a peer review of model performance. On January 31, 1997, the State of Wisconsin entered into a Memorandum of Agreement (Agreement) with seven companies that have primary responsibility for PCB discharges to the Lower Fox River. Those seven companies form the Fox River Group (FRG). One component of the Agreement was to “evaluate water quality models for the Lower Fox River and Green Bay.” The intent was to establish goals to evaluate the quality of model results. As specified by the Agreement, the Model Evaluation Workgroup (Workgroup) was formed. The Workgroup was comprised of technical representatives for the FRG and WDNR in order to undertake “cooperative and collaborative” evaluations of model performance. Development of a series of technical reports followed. While the model evaluation process was ongoing, the FRG also initiated a peer review of model performance that was managed by the American Geological Institute (AGI, 2000).

The reports developed by the Workgroup were each prepared as a Technical Memorandum (TM). A listing of selected Workgroup TMs is presented in Table 3-1. Each TM listed provides detailed analyses of key aspects of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions. These analyses were designed to take maximum advantage of information from a wide array of sources and were not restricted to the exclusive consideration of information generated during GBMBS or LMMBS data collection efforts. The reports examining solids inputs to the River are of particular importance. Successful simulation of PCB (or any hydrophobic chemical) transport is critically dependent on the transport of the particles with which the contaminant is associated. Given that contemporary point and non-point sources of PCBs to the Lower Fox River are near zero (WDNR, 1999a; LTI 1999a; WDNR, 2001a), it is important to distinguish between solids originating from the watershed (which are essentially free of PCBs) and those originating from the sediment bed (which are PCB contaminated). Those reports (TMs 2a, 2b, 2c, 2d, and 3a) consider solids inputs in much greater detail than was possible during the GBMBS and LMMBS. As described in TM3a (WDNR, 2001a), the Workgroup reports listed in Table 3-1 were the source of the majority of the information necessary for model development.

In addition to Workgroup efforts, additional assessments of model performance were presented by a peer review panel. Among the peer review panel recommendations were (AGI, 2000):

1. Use Lake Winnebago as the upstream limit of the model spatial domain to achieve a zero upstream PCB boundary condition (i.e. a point upstream of the PCB contaminated area);

2. Use a numerical integration scheme that avoids mixing in deep sediments; and

3. Treat solids as (at least) three state variables.

To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts. As recommended by the peer review panel, the wLFRM describes PCB transport in River from Lake Winnebago to the River mouth at Green Bay in a single spatial domain, uses the IPX 2.7.4 framework (USEPA, 2001) to avoid mixing in deep sediments, and treats solids as three state variables throughout the model spatial domain.

It is worth noting that the development history of the wLFRM includes three peer-reviewed journal publications: Velleux and Endicott (1994), Velleux et al. (1995), and Velleux et al. (1996). Note that the IPX 2.7.4 computational framework used for wLFRM simulations was derived from the USEPA WASP series of water quality models. Numerous publications regarding development of the WASP framework exist. Beyond this relationship to the WASP series of models, the development history of the IPX framework was also peer-reviewed by USEPA: Velleux et al. (1994) and USEPA (2001). The USEPA (2001) publication is available via the USEPA National Environmental Publications Internet Site on the world wide web at: http://www.epa.gov/cgi-bin/claritgw?op-Display&document=clserv:ORD:0648. At this time, no other model describing PCB transport in the Lower Fox River is as extensively peer-reviewed.

## 3.2 Model Segmentation and Spatial Organization

The full length of the Lower Fox River, from Lake Winnebago to its mouth at Green Bay, was simulated in a single domain. To represent the River in the model framework, this domain was divided into water, surficial sediments, and subsurface sediment layer segments. The optimal choice of segmentation depends on physical characteristics, contaminant concentration gradients, dominant transport processes, and the desired model resolution. Based on these considerations, 40 water column segments and 165 sediment stacks were defined. The sediment stacks were further divided into 165 surface sediment segments, 330 subsurface sediment segments, and 652 deep sediment sections. Groups of segments divide the River into four reaches as presented in Table 3-2. A complete description of wLFRM segmentation is presented by WDNR (2001a).

The physical characteristics of all water column segments (volume, surface area, depth, etc.) were estimated from information presented in National Oceanic and Atmospheric Administration (NOAA) navigation chart number 14916. Additional supporting information was obtained from Lower Fox River hydrographic surveys performed by the U.S. Army Corps of Engineers (USACE) and Ocean Surveys, Inc. (OSI, 1998).

### TABLE 3-1 LIST OF SELECTED MODEL EVALUATION WORKGROUP TECHNICAL REPORTS

| Report[6] | Title/Topic | Source |
|---|---|---|
| Work Plan | Work Plan to Evaluate the Fate and Transport Models for the Fox River and Green Bay | LTI and WDNR (1997) |
| TM1 | Model Evaluation Metrics | LTI and WDNR (1998) |
| TM2a | Simulation of Historical and Projected Total Suspended Solids Loads and Flows to the Lower Fox River, N.E. Wisconsin with the Soil and Water Assessment Tool (SWAT) | FWB2000 (1998) |
| TM2b | Computation of Watershed Solids and PCB Load Estimates for Green Bay | LTI (1999a) |
| TM2c | Computation of Internal Solids Loads in Green Bay and the Lower Fox River | LTI (1999b) |
| TM2d | Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Lower Fox River Point Sources | WDNR (1999a) |
| TM2e | Estimation of Lower Fox River Sediment Bed Properties | WDNR (1999b) |
| TM2g | Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations | WDNR (1999c) |
| TM3a | Evaluation of Flows, Loads, Initial Conditions, and Boundary Conditions | WDNR (2001a) |
| TM5b | ECOM-siz-SEDZL Model Application: Lower Fox River Downstream of the De Pere Dam | Baird (2000a) |
| TM5c | Evaluation of the Hydrodynamics in the Lower Fox River Between Lake Winnebago and De Pere, WI | HQI (2000) |
| TM "5d"[7] | ECOMSED Model Application: Upstream Lower Fox River from Lake Winnebago to De Pere Dam | Baird (2000b) |

6 TM = Technical Memorandum.
7 The designation of this report as TM "5d" is informal based on its relation to companion documents.

## TABLE 3-2 LOWER FOX RIVER REACH DEFINITIONS

| Reach | Description | Water Segments | Sediment Stacks |
|---|---|---|---|
| 1 | Little Lake Butte des Morts (Appleton dam) | 1-7 | 1-11, 47-53 |
| 2 | Appleton to Little Rapids (Little Rapids dam) | 8-18 | 12-37, 54-64 |
| 3 | Little Rapids to De Pere (De Pere dam) | 19-24 | 38-46, 65-70 |
| 4 | De Pere to Green Bay (the River mouth) | 25-40 | 71-165 |

The physical characteristics of all sediment stacks and layers within each stack were estimated from interpolations of field survey results and sediment data collected from 1989 through 1997 as described in TM2e (WDNR, 1999b). Each stack represents one sediment deposit (or sub-deposit division), interdeposit area, or sediment management unit (SMU). These stacks were further divided into 10 vertical layers[8] (to the limit of sediment thickness in any location) as follows, expressed as a distance below the initial position sediment-water interface: 0-5 cm, 5-10 cm, 10-30 cm, 30-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm, and greater than 300 cm. The first three layers in each stack (surface layer and two subsurface layers) were represented as active model segments. Remaining sediments in each stack were represented as deep sediment layers (see USEPA, 2001 for further discussion).

## 3.3 MODEL PARAMETERIZATION AND CALIBRATION

In addition to the overviews provided in preceding section of this White Paper, the development history, structure, parameterization, and calibration of the wLFRM are described in detail by WDNR (2001a). Simulations for the calibration (and forecast) period were performed using the IPX 2.7.4 framework (USEPA, 2001). The major areas of model parameterization and calibration are: loads, boundary conditions, initial conditions, hydrodynamics (flows), sediment transport, and PCB transport.

Details regarding model parameterization and calibration are well described by WDNR (2001a) and the Technical Memoranda developed by the Workgroup in collaboration with the FRG as listed in Table 3-1. In addition to this extensive documentation, USEPA (2001) presents detailed descriptions of the mathematical formulations for mass transport and transfer processes as implemented in the IPX 2.7.4 framework. A summary of wLFRM features and parameterization is presented in Table 3-3. For convenience, an overview of parameterizations and calibrations for hydrodynamics, sediment transport, and PCB transport follow.

The model calibration period was 1989 to 1995. This period was selected for three reasons. First, the majority of field observations to evaluate model performance are for this timeframe. Second, this period is after improved wastewater treatment practices were implemented and PCB discharges to the River were essentially eliminated. Third, conditions during this period (loads, flows, boundary conditions, etc.) are expected to be representative of future conditions.

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8 TM2e defines nine vertical layers. For wLFRM development, the first layer defined in TM2e (0-10 cm) was subdivided into two layers (0-5 cm and 5-10 cm).

### 3.3.1 Hydrodynamics

Water flows into the Lower Fox River from several sources: the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, and point sources. As described in the model evaluation work plan (LTI and WDNR, 1997), these flow sources were examined as part of TM2a (FWB2000, 1998), TM2d (WDNR, 1999a), and TM3a (WDNR, 2001a). Hydrodynamic models of the Lower Fox River were also developed as part of TM5c (HQI, 2000) and TM5b (Baird, 2000a) to examine the structure of river currents. This information was used to describe the magnitude and temporal dynamics of flows and velocities in the wLFRM.

## TABLE 3-3 MODEL FEATURE AND PARAMETERIZATION SUMMARY

| Feature | Value | Basis |
|---|---|---|
| Spatial Domain | 39 Miles (whole River) | Upstream PCB boundary condition is zero; Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997); AGI recommendation (AGI, 2000) |
| Temporal Domain | 1989-1995 (calibration)<br>100 years (long-term forecast) | TM1 (LTI and WDNR, 1998); period of greatest data availability for calibration |
| State Variables | 3 solids types<br>Total PCBs | Multiple particle types needed to represent transport of different particles; TM2d (WDNR, 1999a); AGI recommendation (AGI, 2000) |
| Total Segments | 535 | Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997) |
| Water Segments | 40 | Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997) |
| Surface Sediment Segments | 165 (deposits, interdeposits, SMUs) | GBMBS and other field data; WDNR (1997); TM2e (WDNR, 1999b) |
| Subsurface Sediment Segments | 330 (remaining sediment in “deep layers”) | Two layers under each surface segment to permit description of sediment mixing; radioisotope tracer study (Fitzgerald et al. 2001); TM2g (WDNR, 1999c) |
| Framework | Semi-Lagrangian bed submodel | Avoid mixing in deep sediments; AGI recommendation (AGI, 2000) |
| Sediment Layers (nominal thickness) | 0-5 cm, 5-10 cm, 10-30 cm, 30-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm, 300+ cm | TM2e (WDNR, 1999b); radioisotope tracer study (Fitzgerald et al. 2001) results help define 5 cm surface layer thickness |
| Flow | Average: 146 $m^3/s$<br>Range: 29.5 to 667 $m^3/s$ | Observed flow at Rapide Croche extrapolated to include downstream inputs; TM2a (FWB2000, 1998); TM3a (WDNR, 2001a) |
| Upstream Boundary Loads | Solids: 68,000 MT/year<br>PCBs: 0 | Measurements at Lake Winnebago (1986-90); Gustin (1995); Steuer et al (1995); TM3a (WDNR, 2001a) |
| Watershed Loads | Solids: 54,000 MT/year<br>PCBs: 7.5 kg/year | TM2a (FWB2000, 1998); TM2b (LTI, 1999a), TM3a (WDNR, 2001a) |
| Internal Loads | Solids: 20,000 MT/year<br>PCBs: not applicable | TM2c (LTI, 1999b) |
| Point Source Loads | Solids: 4,000 MT/year<br>PCBs: 12.25 kg/year | TM2d (WDNR, 1999a) |
| Initial Conditions | sand, silt, clay, bulk density, organic carbon, PCBs | TM2e (WDNR, 1999b) |

## TABLE 3-3 MODEL FEATURE AND PARAMETERIZATION SUMMARY

| Feature | Value | Basis |
|---|---|---|
| Feature | Value | Basis |
| Water Velocity | $U_{ij} = F_{LSij}(a\ Q^b)$ | TM5c (HQI, 2000), TM5b (Baird, 2000a) |
| Shear Stress | $\tau = C_f\ \rho U^2$<br>$C_f \approx 0.003$ | TM5c (HQI, 2000), TM5b (Baird, 2000a) |
| Coarse Settling | $V_s$ = 470 m/day<br>$\tau_{cd}$ = 0.80 dynes/cm$^2$ | Gessler (1967); Cheng (1997); force balance |
| Medium Settling | $V_s$ = 2.15-3.9 m/day<br>$\tau_{cd}$ = 0.15 dynes/cm$^2$ | Partheniades (1992); Burban (1990); Chapra (1997) |
| Fine Settling | $V_s$ = 0.1 m/day<br>$\tau_{cd}$ = 0.10 dynes/cm$^2$ | Partheniades (1992); Wetzel (1983); Chapra (1997) |
| Event Resuspension | Epsilon Equation<br>$V_r$ varies as a function of $\tau$<br>$\tau_c$ = 1 dyne/cm$^2$<br>$a_0 = 0.75 - 1.5 \times 10^{-3}$<br>m = 2.3<br>Z = 1.74 | Lick et al. (1995); TM5b (Baird, 2000a); TM5d (Baird, 2000b); Gailani et al. (1991) |
| "Background" Resuspension | In form of Epsilon Equation<br>$V_{rb}$ varies as a function of $\tau$<br>Average: $V_{rb} \approx$ 0.7 cm/year | interpretation of "fluff" layer resuspension as described by Gailani et al. (1991) |
| Partitioning | $K_{oc} = 10^{6.3}$<br>$\nu_x = 9$ | GBMBS field data; Velleux and Endicott (1994) |
| Volatilization | $\ln K_H = 18.53 - 7868/T$<br>$K_L$ = modified O'Connor-Dobbins<br>$K_G$ = O'Connor/Rathbun | Tateya et al. (1988); Velleux and Endicott (1994) |
| Sediment Diffusion | $K_f = 2 \times 10^{-8}$ m$^2$/s ($\approx$ 3.5 cm/day) | After QEA (1999) |
| Sediment Mixing | $E_M = 1 \times 10^{-10}$ m$^2$/s | Interpretation of field data; TM2g (WDNR, 1999c) |
| PCB Biodegradation | $k_B = 0$ | McLaughlin (1994) |

The velocity at which water moves over the sediment bed surface is the key determinant of the shear stress that is exerted at the sediment-water interface. The shear stress is a controlling factor in the transport of particle-associated contaminants that originate from the sediment bed. The hydrodynamics of the Lower Fox River were examined as part of Workgroup efforts. Technical Memorandum 5c (TM5c) (HQI, 2000) examined hydrodynamics between Lake Winnebago and the De Pere dam. Technical Memorandum 5b (TM5b) (Baird, 2000a) examined hydrodynamics (and sediment transport) between the De Pere dam and the River mouth. For both efforts, two-dimensional hydrodynamic models were constructed and calibrated to available data (flow, water surface elevation, etc.). As described in TM5c and TM5b, the comparison between simulated and observed water surface elevations and flow was excellent. For example, as presented in TM5c regression analyses of the hydrodynamic model results and observed values yielded correlation coefficients greater than or equal to 0.98. This indicates that the hydrodynamic models are appropriate tools for simulating river currents. The hydrodynamic models were then used to develop relationships between the currents the average river flow reported at the Rapide Croche gauging station. These relationships were expressed in the form of a power function as shown in Equation 3.1 of WNDR (2001a).

In general, the correlation between the simulated velocity at each cross-section and observed flow was quite good. With very few exceptions, correlation coefficients ($r^2$) were generally 0.85 or greater. This indicates that the relationships between flow and velocity are strong. Therefore, especially for long-term simulations, flow can be used to estimate velocity. Hydrodynamic model results were integrated within the wLFRM through use of the relationships defined by regressions with the form of Equation (3.1). For areas downstream of the De Pere dam, velocities at all grid cells within each SMU were averaged prior to regression. Estimates of sediment transport (erosion and deposition fluxes) based on these flow-velocity relationships are described in Section 3.3.2. The parameterization of flow velocity in the wLFRM is well within the range of expected values for this process.

### 3.3.2 Sediment Transport

Solids enter the Lower Fox River from several sources: the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, internal production, point sources, and the sediment bed. As described in the model evaluation work plan (LTI and WDNR, 1997), these solids sources were examined as part of TM2a (FWB2000, 1998), TM2c (LTI, 1999b), TM2d (WDNR, 1999a), TM2e (WDNR, 1999b), and TM3a (WDNR, 2001a). After entering the River, solids and particulate phase chemicals exchange between the water column and the sediment bed as a result of sediment transport processes: resuspension (erosion) and settling (deposition). The shear stress at the sediment-water interface (generated by water flowing over the River bed) is a key determinant of the extent to which materials are incorporated into the bed or are resuspended. Sediment transport models of the Lower Fox River were developed as part of TM5b (Baird, 2000a) and TM5d (Baird, 2000b) to explore interactions between the water column and sediment bed. This information was used to describe sediment transport in the wLFRM.

Suspended solids were simulated as three state variables: coarse, medium, and fine. Total solids is the sum of these three solids classes. Separation of total solids into three classes was based on expected differences in the sediment transport properties of various particulate materials and particle grain size. Note that while grain size is an indicator of solids class, it was not the main determinant. For example, algal particles may have diameters in the silt size range but exhibit quiescent settling speeds far less than those of silts. This parameterization approach is consistent with models developed for other sites such as the Hudson River as well as prior generations of model development for the Lower Fox River.

#### *3.3.2.1 Shear Stresses at the Sediment-Water Interface*

As water flows over the sediment bed, shear stresses are generated. The magnitude of these shear stresses is a key determinant in the transport of material between the water column and sediment bed. As described in TM5c (HQI, 2000) and TM5b (Baird, 2000a), shear stresses were computed from water velocities as shown in Equation 3.6 of WDNR (2001a).

In the wLFRM, water velocities were estimated from the flow-velocity relationships computed using hydrodynamic model results as described in Section 3.3.1. Shear stresses were estimated from velocity using Equation 3.6. Water velocity and shear stress functions were computed for the area over each sediment deposit (including sub-deposit divisions), interdeposit, and SMU. The coefficient of friction used for shear stress computations was approximately 0.003 as determined by calibration of the hydrodynamic models presented in TM5c (HQI, 2000), and TM5b (Baird, 2000a). The parameterization of shear stress in the wLFRM is well within the range of expected values for this process.

#### 3.3.2.2 Settling and the Probability of Deposition (Deposition)

Settling velocities and probability of deposition parameters were specified for each of the three particles types simulated. Coarse particles are typically non-cohesive and have settling velocities of hundreds to thousands of meters per day under quiescent conditions depending on particle size (Julien, 1998). In the wLFRM, settling velocities for the coarse size class (~100 µm) were set to 470 m/day using the relationship described by Cheng (1997). Probabilities of deposition were computed using the approach described by Gessler (1967). Medium particles are often cohesive and may flocculate. Floc settling velocities depend on the conditions under which the floc was formed (Burban et al. 1990) and range from 2 to 10 m/day under conditions found in freshwater tributaries. In the wLFRM, settling velocities for the medium size class ranged by season from 2.15 to 3.9 m/day. Fine particles may not extensively flocculate and typically have relatively small settling velocities as a result of their size, shape, density, and other physicochemical properties. For example, clay particles often have negative electrical charges that inhibit flocculation. Other fine particles such as algae generally have mechanisms (such as gas vacuoles) to minimize their settling velocities (Wetzel, 1983). As a result of these attributes and other conditions, fine particles may have near-zero settling velocities. In the wLFRM, settling velocities for the fine size class were set to 0.1 m/day. Probabilities of deposition for medium and fine particles were computed using the approach described by Partheniades (1992). The parameterization of deposition in the wLFRM is well within the range of expected values for this process.

#### 3.3.2.3 Resuspension (Erosion)

The particle resuspension flux was described as a function of the shear stress at the sediment-water interface (Ziegler et al. 1988; Gailani et al. 1991) as described by Equation 3.18 of WDNR (2001a). From the resuspension flux, a resuspension velocity was computed as described by Equation 3.19 of WDNR (2001a).

In the wLFRM, resuspension parameters were selected based on the results of studies of Lower Fox River sediments as reported by Xu (1991) and Lick et al. (1995). The erosion potentials of sediments from twelve locations between the De Pere dam and the River mouth (Reach 4) are presented in Figure 3-1. These measurements were made with the Shaker device. Seven of the twelve samples tested were classified as "soft mud", one sample was classified as "silt," and the remaining four samples were classified as "sandy." As noted by Lick et al. (1995), in the Lower Fox River from the De Pere dam to the East River, the sediments were primarily soft mud. Also as noted, from the East River junction to the mouth of the Lower Fox River, nearshore areas were generally muddy while deeper areas were sandy with pockets of muds. Given the overall predominance of sediments classified as soft mud (and the expected preference of PCBs for such materials due to their greater organic carbon content and particle surface areas), the sediments were assumed to behave as soft mud. The average critical shear stress ($\tau_c$) was assumed to be 1 dyne/cm$^2$. The sediment resuspension exponent (m) was assumed to equal 2.3. The sediment yield coefficient varied by reach as follows: $1.5 \times 10^{-3}$ (Reaches 1, 3); $7.5 \times 10^{-4}$ (Reach 2); and $1.0 \times 10^{-3}$ (Reach 4). The sediment age constant (Z) was assumed to equal 1.74. Resuspension amounts as a function of shear stress for this parameterization are also presented in Figure 3-1. As shown in Figure 3-1, the parameterization of erosion in the wLFRM is well within the range of field observations.

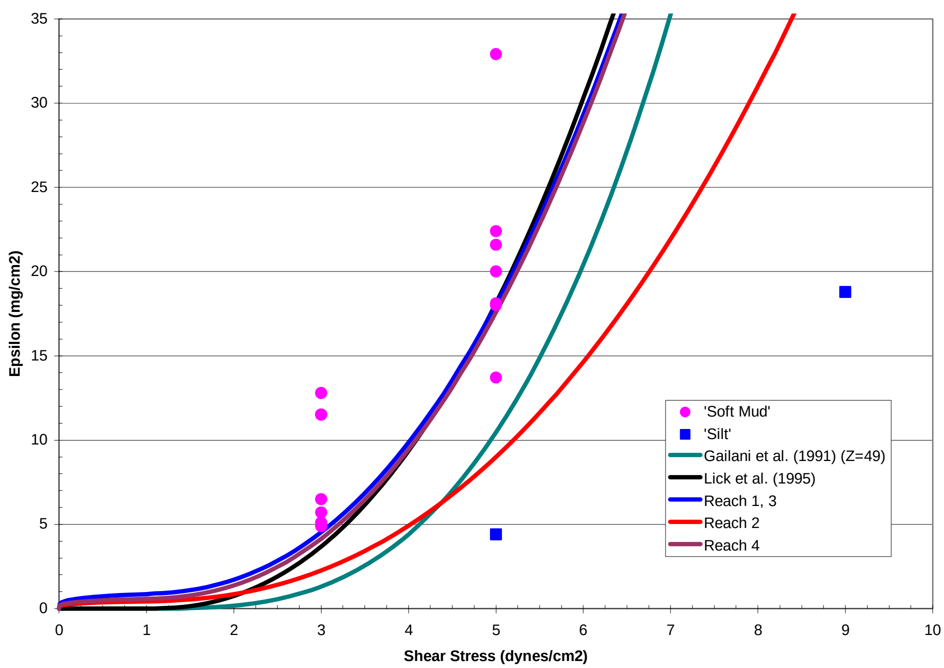


**FIGURE 3-1 REPRESENTATION OF EROSION POTENTIALS AS PARAMETERIZED IN THE wLFRM**

#### *3.3.2.4 Displacement of the Sediment-Water Interface (Burial and Scour)*

When particles are added to or removed from the sediment bed, the vertical position (elevation) of the sediment water interface is displaced relative to a fixed reference location (datum). Addition of particles to the bed causes bed elevation to increase (burial). Removal of particles from the bed causes bed elevations to decrease (scour). Addition of particles to the bed occurs through deposition (settling). Removal of particles occurs through erosion (resuspension). The difference between the fluxes of material entering and leaving the bed defines the direction and magnitude of sediment-water interface displacement.

In the wLFRM, sediment bed elevation changes are computed directly from the difference between the deposition and erosion fluxes for each sediment stack. No parameters to explicitly define the direction or magnitude of sediment-water interface displacements were specified. For each sediment stack, the reference location for displacements was the hard bottom of the sediment column determined from sediment thickness observations as described in TM2e (WDNR, 1999b). Note that no material can ever move into or out of the model network across the hard bottom of the sediment column. Further discussion of this representation of burial and scour is presented in USEPA (2001).

#### *3.3.2.5 Sediment Mixing Processes*

As described in Section 2.5, disturbances of sediments by bioturbation and other events can mix particles (and particle-associated contaminants) within the sediment column. Mixing can cause PCB initially present deeper in the sediment column to return to the sediment surface. In the wLFRM, sediment mixing was specified to occur between the top three layers of the sediment column. Typically, this corresponds to mixing depths of 10 to 30 cm. This is consistent mixed layer depths determined from bioturbation, Be-7, and Cs-137, and bed elevation change data as described in Section 2.5. As bed elevations change, the mixing depths can also change. In areas were large bed elevations decreases occur, maximum mixing depths of 75 to 150 cm are possible in the model. This is also consistent observed Cs-17 and bed elevation change data as described in Section 2.5. However, it should be noted that effective mixing depths typically do not exceed the 10 cm (between layers 1 and 2) to 30 cm (between layers 1 and 2) horizons. Sediment mixing coefficients in the wLFRM were set a value of $1.0 \times 10^{-10}$ $m^2/s$ for the spring, summer and fall months and set to zero for the winter months. This is again consistent with mixing rates determined from bioturbation, Be-7, and Cs-137, and bed elevation change data as described in Section 2.5.

### 3.3.3 PCB Transport

PCBs can enter the Lower Fox River from several sources (if present in those sources): the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, point sources, and the sediment bed. As described in the model evaluation work plan (LTI and WDNR, 1997), these possible PCB sources were examined as part of TM2a (FWB2000, 1998) (see TM3a), TM2d (WDNR, 1999a), TM2e (WDNR, 1999b), and TM3a (WDNR, 2001a). This information was used to describe the magnitude and temporal dynamics of PCB inputs in the wLFRM.

PCBs were simulated as one state variable: total PCBs. Total PCBs represents a family of 209 possible related compounds. Each of these different PCB compounds is known as a congener. Total PCBs is the sum of all congeners present. Consistent with observations, PCB loads from Lake Winnebago were set to zero (WDNR, 2001c). PCB loads from the watershed and point source discharges were set to the values described in TM3a (WDNR, 2001c) and TM2d (WDNR, 1999a). PCB levels in the sediment bed were defined in TM2e (WDNR, 1999b). Parameters for PCB mass transfer processes (partitioning, volatilization, porewater diffusion, etc.) were set to values described by WDNR (2001a) as summarized in Table 3-3. The PCB biodegradation rate was set to zero based on the findings of McLaughlin (1994). Each of these parameterizations is consistent with observed conditions and published literature.

Note that porewater diffusion is one of the possible mass transfer pathways for PCBs in the sediments. This process is included in the conceptual model framework as described by WDNR (2001a). Porewater transfers can move dissolved PCBs between sediment layers and to the water column. In the wLFRM, PCB porewater transfer functions were specified between layers in the sediment column. However, due to an oversight when the model input data file was constructed, the linkage between the surface sediments and the water column was not specified. Note that porewater diffusion can only transport dissolved and bound phase PCBs. Also note that PCBs are strongly associated with particles because they are hydrophobic and that less than 1 percent of the PCBs in the sediments are expected to be associated with dissolved and bound phases. As a result, the impact of this oversight is expected to be very small.

# 4 wLFRM PERFORMANCE COMPARISON TO OBSERVED TRENDS AND CONDITIONS

Model performance was evaluated by comparing wLFRM results to the observed trends and conditions described in Section 2. The metrics (standards) used to evaluate model performance are described in Section 4.1. Comparisons of model results to observed trends and conditions for water and sediment are presented in Section 4.2. Discussions of a range of factors that affect model performance are then presented in Section 4.3.

## 4.1 MODEL EVALUATION METRICS

Model evaluation metrics are comparative standards used to assess model performance. Model quality criteria express the idealized level of correspondence between model results and observed conditions. The metrics and quality criteria for this assessment are described in Technical Memorandum 1 (TM1) (LTI and WDNR, 1998). These metrics and criteria were developed jointly by the FRG and WDNR as part of Workgroup efforts to facilitate comparison of model results (output) and observations. The relative difference between model results and observations quantifies model performance and provides an indication of overall model quality. The model quality criteria identified in TM1 was that the mean value of model results for solids and PCBs should be within ±30 percent of observed values in the water column and sediments. The metrics fall into four general categories as shown in Table 4-1. These metrics were used to assess the quality of model results for water and sediments and can be applied to solids or chemicals. Time series metrics were used to compare trends and magnitudes of model results and observations over time at one location. Frequency distribution metrics were used to compare statistical properties. Point-in-time and cumulative performance metrics were used for comparisons over many locations at one point in time or for a specified time period. Specific condition metrics were used to compare model results and observations for specific conditions such as high flow periods or a particular time of year. Further descriptions of these metrics are presented in TM1 (LTI and WDNR, 1998).

### TABLE 4-1 TM1 GENERAL CATEGORIES OF MODEL EVALUATION METRICS

| Metric Category | Media | Application | Use |
|---|---|---|---|
| Time Series | water | solids, PCBs | Trend and magnitude over time at one location |
| Frequency Distributions | water, sediment | solids, PCBs | Statistical properties |
| Point-in-Time/Cumulative Performance:<br>End of period mass balance<br>Sediment bed elevation change<br>Net burial rate (sediment trap efficiency) | water, sediment<br>sediment<br>sediment | PCBs<br>solids<br>solids | Trend and magnitude over many locations at one time or specified time periods |
| Specific Condition Performance[9] | water | solids, PCBs | Trend and magnitude as functions of river conditions such as flow, time of year, etc. |

9 In TM1, this metric category was described as event and non-event concentration and flux comparisons.

## 4.2 EVALUATION OF MODEL PERFORMANCE

The model calibration period was 1989 to 1995. Simulation results for this period were evaluated according to the metrics and criteria identified in TM1 (LTI and WDNR, 1998). The overall appropriateness of the model is judged by the level of agreement between field observations and simulation results using the model metrics. Evaluations for the water column and sediment are presented in the sections that follow.

### 4.2.1 Water Column

For the water column, observations exist to permit evaluation for time series, frequency distribution, point-in-time/cumulative performance, and specific condition metrics. Time series and frequency distribution comparisons of observations and model results were developed for each of the five River monitoring stations: Appleton, Kaukauna, Little Rapids, De Pere, and the River mouth. Model performance assessments for these metrics at the Appleton and River mouth stations are presented in Figures 4-1 through 4-8. Comparisons at the other monitoring stations are presented in WDNR (2001a). The time series comparisons indicate that model results agree with the trend and magnitude of observations. However, the results are generally less than observed values indicating that the model has a low bias. Note that model results are also less than the maximum observed values. Model results are nonetheless in satisfactory agreement with observed values and meet the ±30 percent quality criteria established in TM1 based on frequency distribution comparisons. A summary of calibration simulation performance for solids and PCBs in the water column based on frequency distribution comparisons is presented in Table 4-2.

Cumulative performance comparisons were developed for the River mouth monitoring station at Green Bay. The USGS estimated PCB export to Green Bay for 1989 and 1990 (House et al. 1993) and also for 1994 and 1995 (USGS, 1999). Comparisons of USGS PCB export estimates and model results for these two time periods are presented in Figure 4-9 and 4-10. Overall, model results are about 27 percent less than the USGS estimates. This again indicates that the model has a low bias. Model results are nonetheless in satisfactory agreement with USGS estimates and meet the ±30 percent quality criteria established in TM1 based on these cumulative performance comparisons. A summary calibration simulation performance for PCBs in the water column based on cumulative PCB export comparisons is presented in Table 4-3.

## TABLE 4-2 FREQUENCY DISTRIBUTION COMPARISONS FOR THE WATER COLUMN

| Constituent | Relative Difference Between Mean Observed and Modeled Concentrations by Monitoring Site | | | | | | |
|---|---|---|---|---|---|---|---|
| | Appleton | Kaukauna | Little Rapids | De Pere | River Mouth | Average (All Sites) | Average (4 sites)[10] |
| TSS | -19.5% | -13.5% | -8.6% | -5.8% | -32.4% | -16.0% | -17.8% |
| PCBs | -40.5% | -31.0% | -73.3% | -31.0% | -16.8% | -38.5% | -29.8% |

10 Average of four sites: Appleton, Kaukauna, De Pere, and the river mouth.

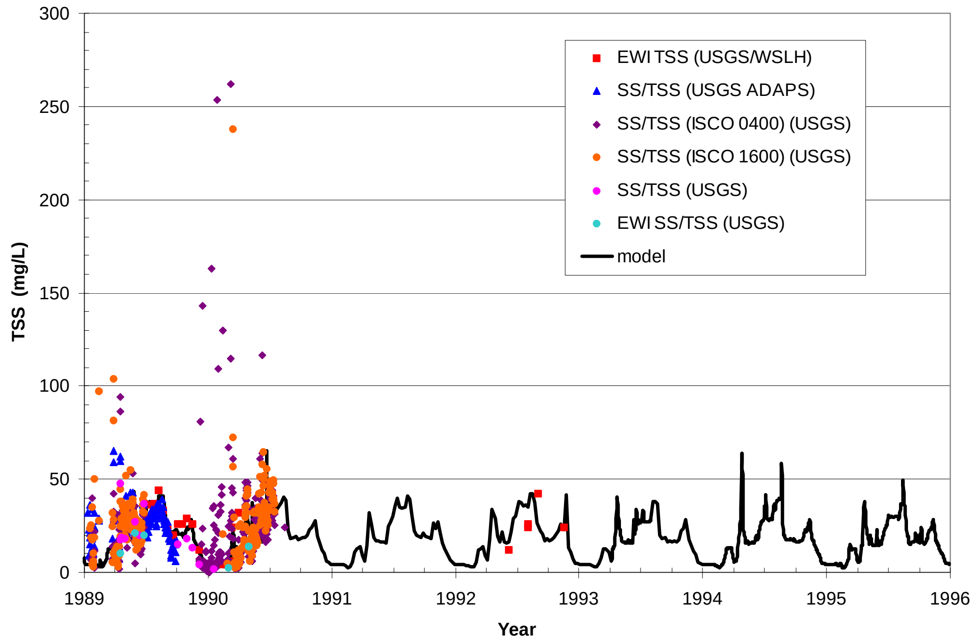


**FIGURE 4-1 TIME SERIES OF WATER COLUMN SOLIDS CONCENTRATIONS AT APPLETON: 1989-1995**

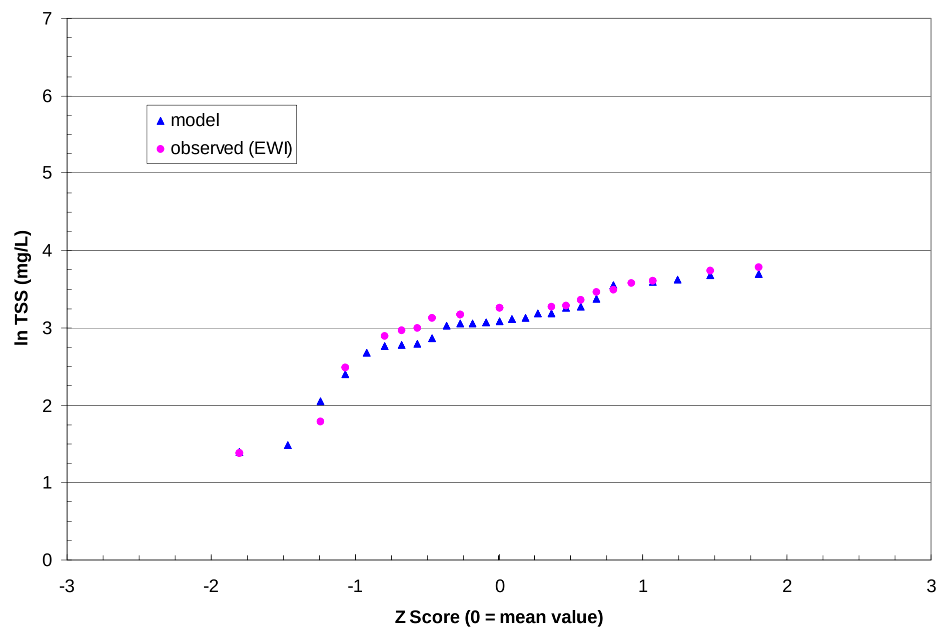


**FIGURE 4-2 FREQUENCY DISTRIBUTIONS OF WATER COLUMN SOLIDS CONCENTRATIONS AT APPLETON: 1989-1995**

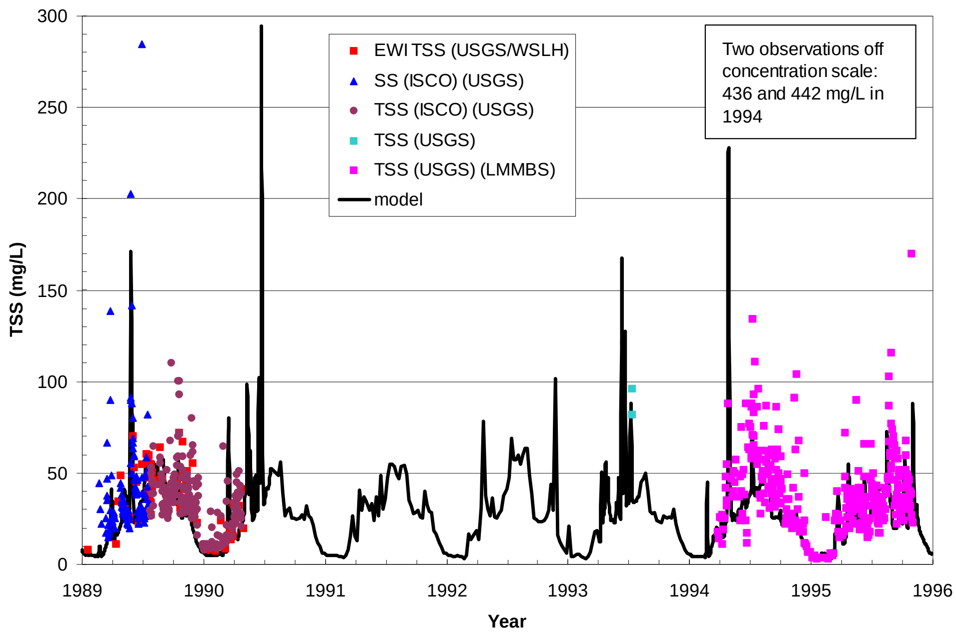


**FIGURE 4-3 TIME SERIES OF WATER COLUMN SOLIDS CONCENTRATIONS AT THE RIVER MOUTH: 1989-1995**

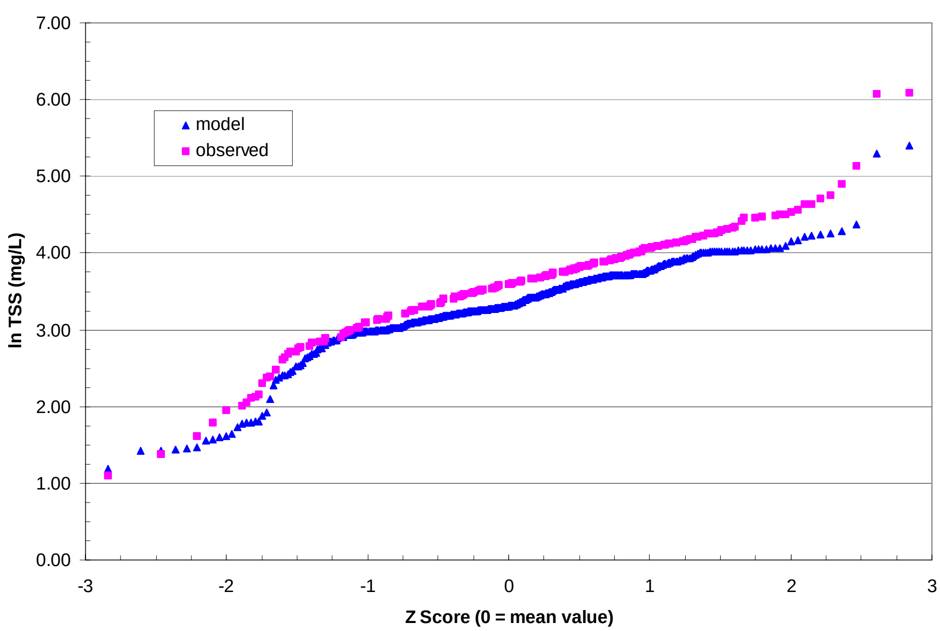


**FIGURE 4-4 FREQUENCY DISTRIBUTIONS OF WATER COLUMN SOLIDS CONCENTRATIONS AT THE RIVER MOUTH: 1989-1995**

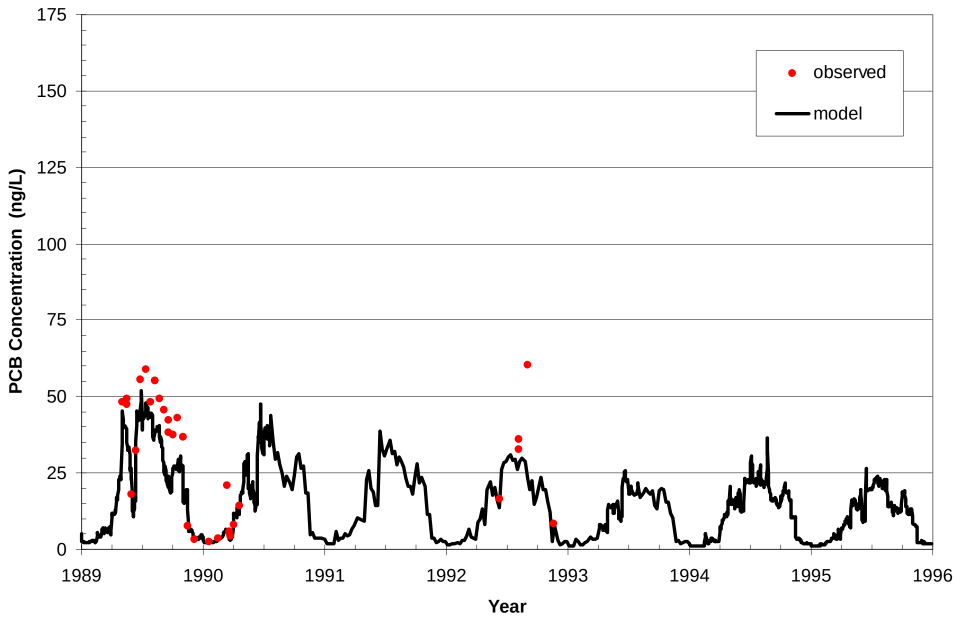


**FIGURE 4-5 TIME SERIES OF WATER COLUMN TOTAL PCB CONCENTRATIONS AT APPLETON: 1989-1995**

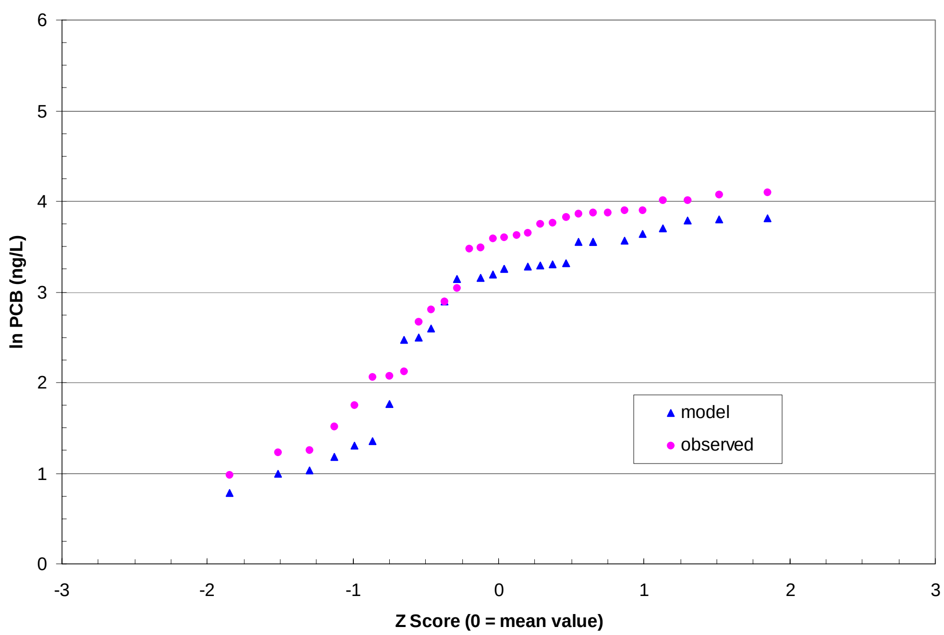


**FIGURE 4-6 FREQUENCY DISTRIBUTIONS OF WATER COLUMN TOTAL PCB CONCENTRATIONS AT APPLETON: 1989-1995**

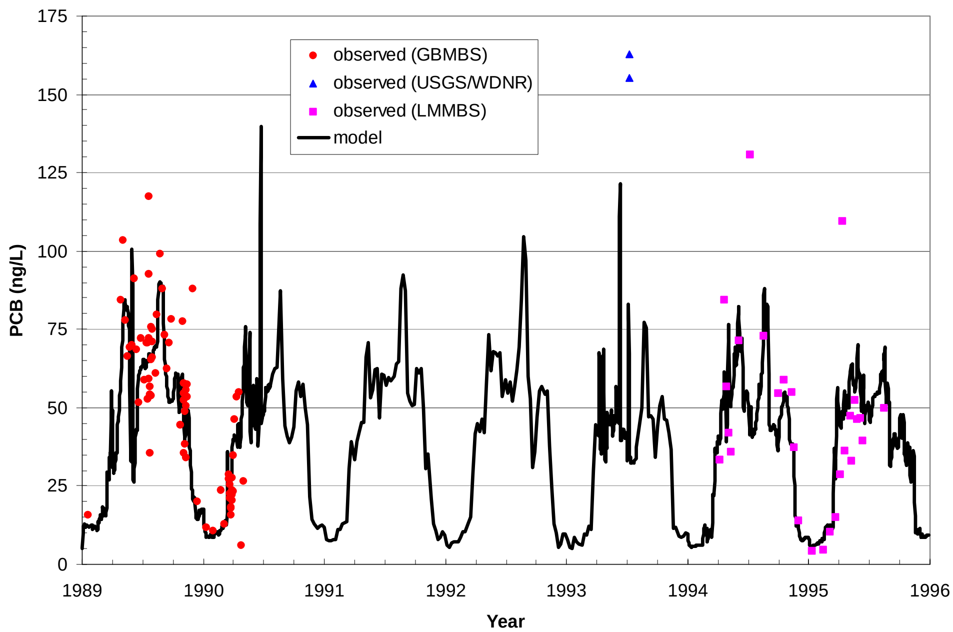


**FIGURE 4-7 TIME SERIES OF WATER COLUMN TOTAL PCB CONCENTRATIONS AT THE RIVER MOUTH: 1989-1995**

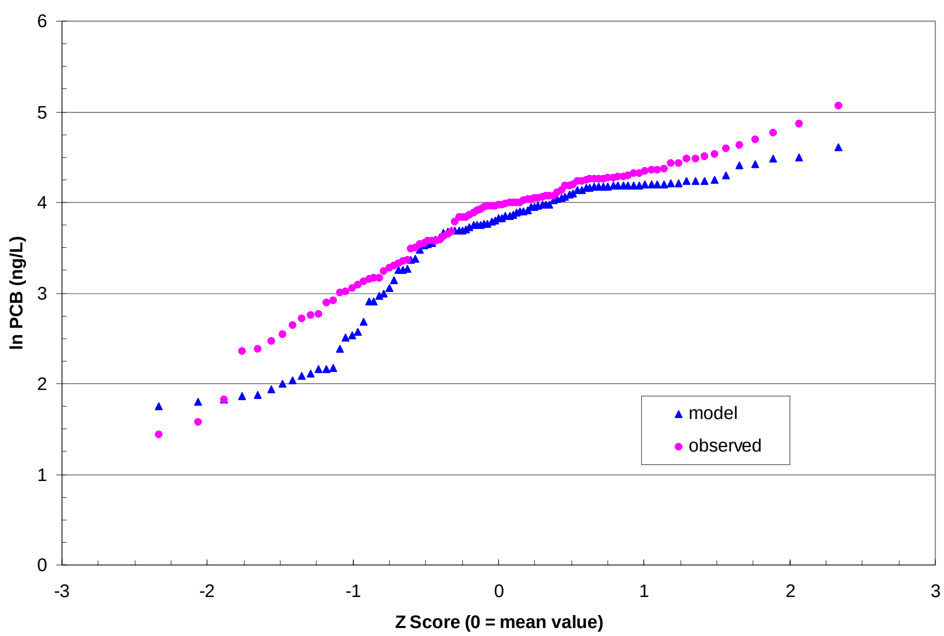


**FIGURE 4-8 FREQUENCY DISTRIBUTIONS OF WATER COLUMN TOTAL PCB CONCENTRATIONS AT THE RIVER MOUTH: 1989-1995**

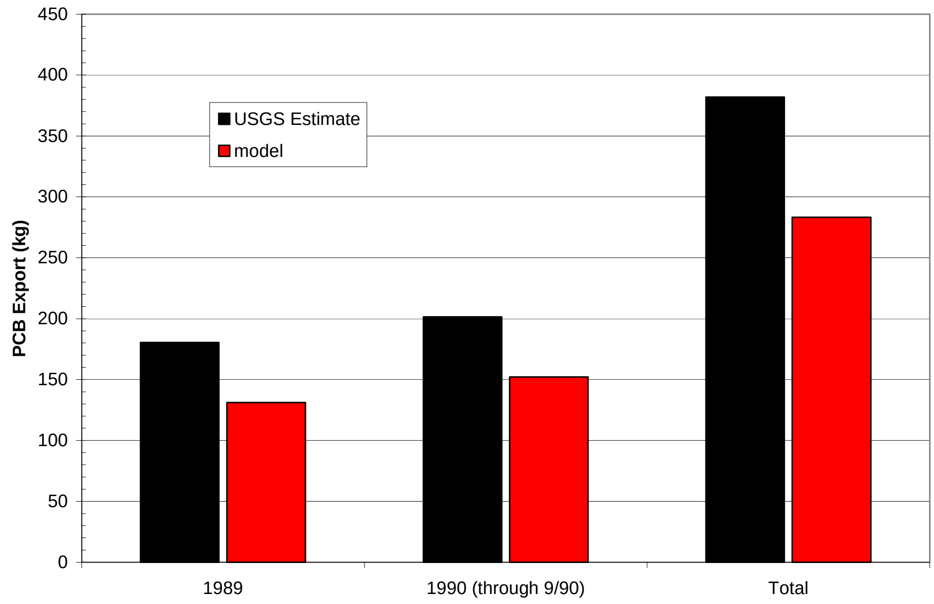


**FIGURE 4-9 COMPARISON OF CUMULATIVE PCB EXPORT TO GREEN BAY: 1989-1990**

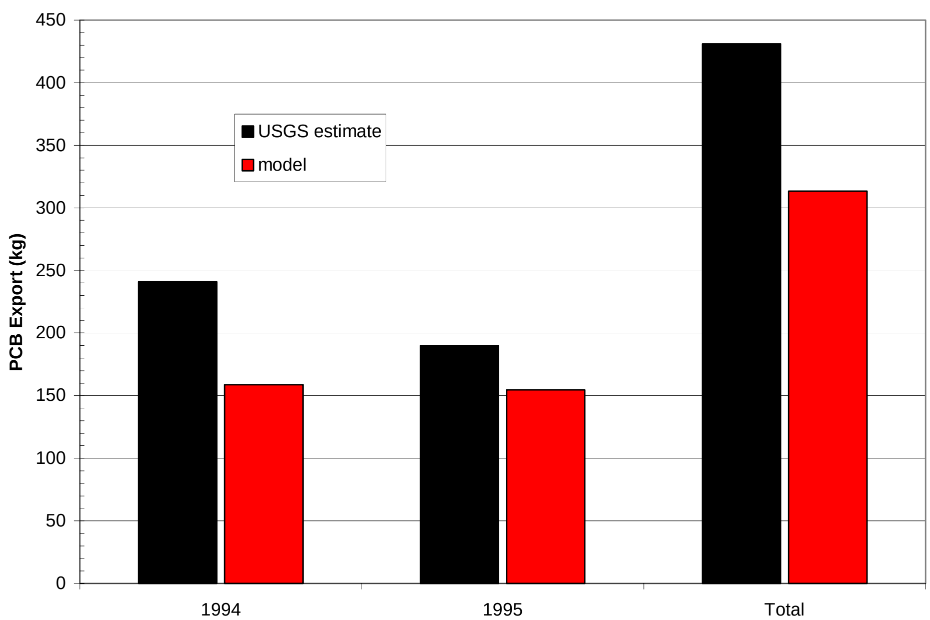


**FIGURE 4-10 COMPARISON OF CUMULATIVE PCB EXPORT TO GREEN BAY: 1994-1995**

## TABLE 4-3 COMPARISON OF CUMULATIVE PCB EXPORT TO GREEN BAY: 1989-1990

| Time Period | wLFRM PCB Export (kg) | USGS Estimated PCB Export (kg) | Difference (%) |
|---|---|---|---|
| 1989 (1/1 - 12/31) | 131 | 180 | -27.4 |
| 1990 (1/1 - 9/30) | 152 | 201 | -24.5 |
| *Total (1/1/89 - 9/30/90)* | *283* | *381* | *-25.9* |
| 1994 (1/1 - 12/31) | 159 | 241 | -34.0 |
| 1995 (1/1 – 12/31) | 155 | 190 | -18.4 |
| *Total (1/1/94 - 12/31/95)* | *314* | *431* | *-27.1* |
| **Cumulative Total** | **597** | **812** | **-26.5** |

## TABLE 4-4 SPECIFIC CONDITION COMPARISONS FOR THE WATER COLUMN

| Constituent | Mean Relative Difference Between Observed and Model Concentrations by Monitoring Site[11] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Appleton | Kaukauna | Little Rapids | De Pere | River Mouth | Average (All Sites) | Average (4 sites) |
| TSS | -2.0% | -2.2% | -6.5% | 1.0% | -1.8% | -1.5% | -0.1% |
| PCBs | 18.0% | 2.4% | 46.7% | -18.0% | 20.7% | 14.0% | 5.8% |

Specific condition (concentration-flow) comparisons of observations and model results were developed for each of the five River monitoring stations: Appleton, Kaukauna, Little Rapids, De Pere, and the River mouth at Green Bay. Model performance assessments for these metrics at the Appleton and River mouth stations are presented in Figures 4-11 through 4-14. Comparisons at the other monitoring stations are presented in WDNR (2001a). At all five monitoring stations, water column solids and PCB observations exist for a wide range of flows. In general, the comparisons indicate that model results agree with the trend and magnitude of the observations. However, it is worth noting that model results are often less than observed values at flows greater than 200 $m^3$/s. This again indicates that the model has a low bias. Model results are nonetheless in satisfactory agreement with observed values and meet the ±30 percent quality criteria established in TM1 based on these specific condition comparisons. A summary of calibration simulation performance for solids and PCBs in the water column based on specific condition performance comparisons is presented in Table 4-4.

11 Differences computed from signed errors. Across the range of flows, errors offset each other. Average root mean square (RMS) errors (relative to the mean) were much larger: 42.6 percent for solids and 65.8 percent for PCBs. However, note that RMS errors can be sensitive to a few large differences between simulated and observed values.

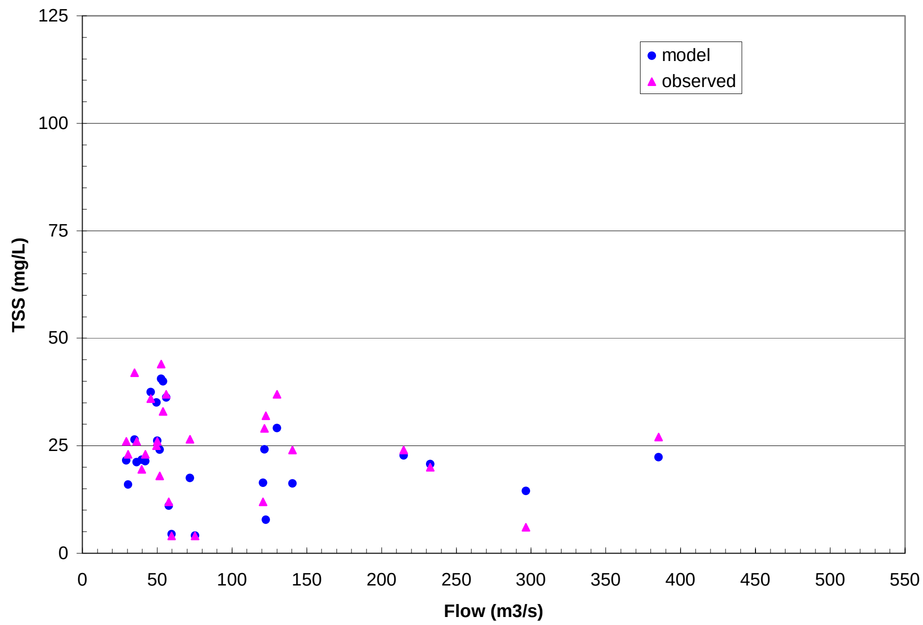


**FIGURE 4-11 WATER COLUMN TSS CONCENTRATION VERSUS RIVER FLOW AT APPLETON: 1989-1995**

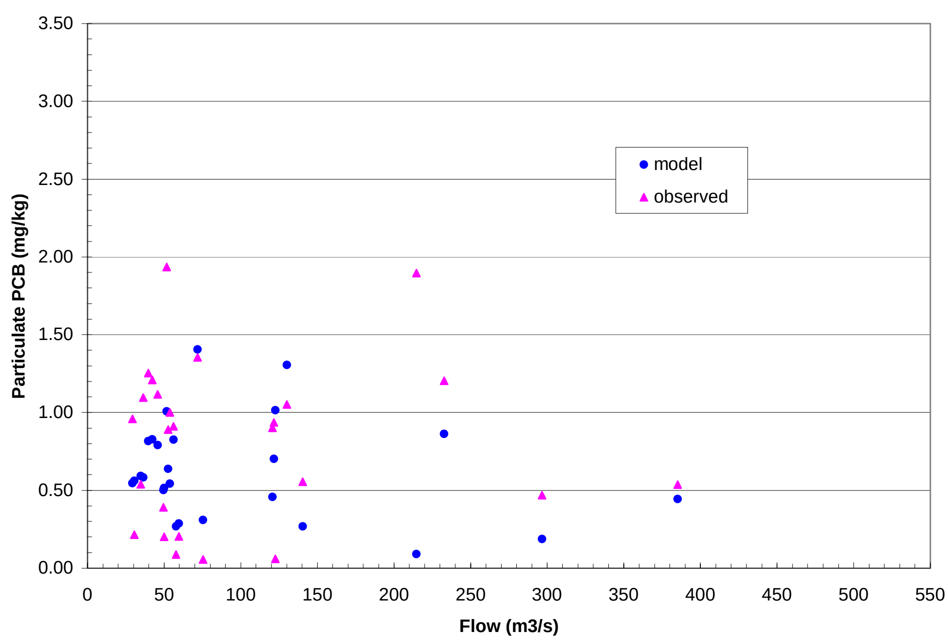


**FIGURE 4-12 WATER COLUMN PARTICLE-ASSOCIATED PCB CONCENTRATION VERSUS RIVER FLOW AT APPLETON: 1989-1995**

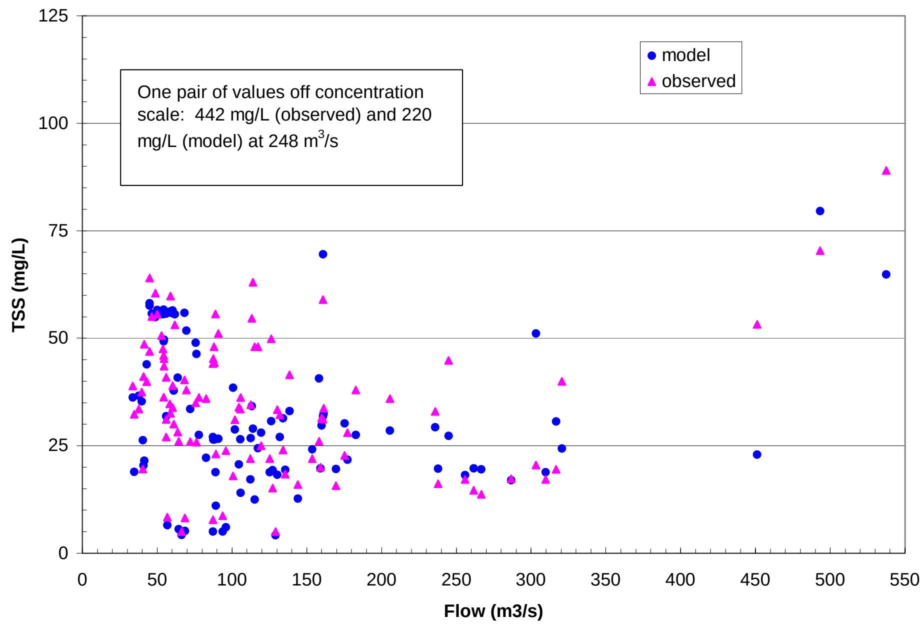


**FIGURE 4-13 WATER COLUMN TSS CONCENTRATION VERSUS RIVER FLOW AT THE RIVER MOUTH: 1989-1995**

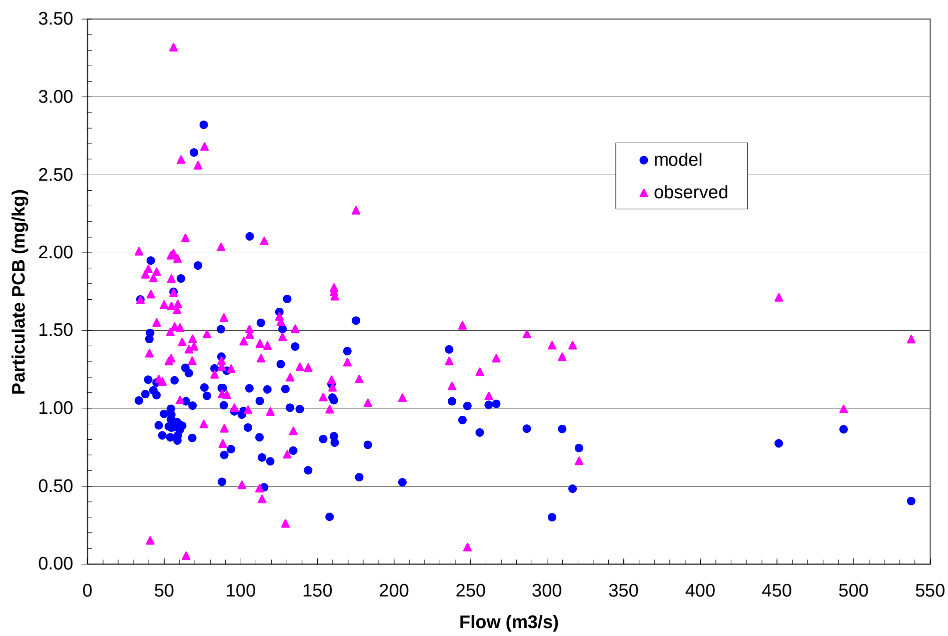


**FIGURE 4-14 WATER COLUMN PARTICLE-ASSOCIATED PCB CONCENTRATION VERSUS RIVER FLOW AT THE RIVER MOUTH: 1989-1995**

### 4.2.2 Sediments

For sediments, observations or inferences exist to permit evaluation for point-in-time/cumulative performance metrics. Evaluations can be constructed to examine sediment bed elevation changes, net sediment burial rates and trap efficiencies, and sediment PCB concentration trends. Model performance assessments relative to these metrics are presented in the sections that follow.

#### *4.2.2.1 Sediment Bed Elevation Change Comparisons*

Cumulative performance comparisons of observed sediment bed elevation changes and model results were developed for a series of hydrographic survey stations and station groups presented in TM2g (WDNR, 1999c): T10; 370+00, 360+00, and T9; 205+00 and T5; 91+00; and 61+00 and T3. As most bed elevation data are restricted to the River navigation channel, most of the stations selected for comparisons are located between the De Pere dam and the River mouth. Station T10 is located just upstream of the De Pere dam in the area of Deposits GG and HH. Stations 370+00, 360+00, and T9 are located just downstream of the De Pere dam in the area of SMUs 20-25. Stations 205+00 and T5 are located approximately 3.9 miles (6.2 km) upstream of the River mouth near the Fort James (Georgia Pacific) West mill in the area of SMUs 50-55. Station 91+00 is located just upstream of the East River turning basin, approximately 1.7 miles (2.8 km) upstream of the River mouth, in the area of SMUs 86-91. Stations 61+00 and T3 are located just downstream of the East River turning basin, approximately 1.2 miles (1.8 km) upstream of the River mouth, in the area of SMUs 92-97. Comparisons of sediment bed elevation changes are presented in Table 4-5.

In general, model results can differ from observed values. For the comparisons in Table 4-5, model results are 83 percent less than the observations on average. For many of the locations and time periods examined, the results may match the direction of the observations (increase or decrease) but differ in scale. For other locations and times, results differ from observations in terms of both direction and scale. However, it is important to consider the nature of the observations and results. Observed values represent conditions along a line. USACE hydrographic surveys demonstrate that bed elevations along a line can differ widely from station to station. In contrast, model results represent average conditions for large areas. Given the wide station-to-station variations, the average elevation across a large area can be distinctly different than the average elevation along an individual transect line. Consequently, comparisons between these observations and model results may not indicate the quality of model performance.

More importantly, significant differences between the scales of observed bed elevation changes and model results are expected. As described in TM5b (Baird, 2000a) and TM5d (Baird, 2000b), the underlying sediment transport models on which the wLFRM is based do not capture the scale of observed bed elevation changes. Moreover, no sediment transport model ever developed for this Site to date has been able to capture the range of observed bed elevation changes over time. As a consequence of the limitations of the underlying sediment transport models, the wLFRM does not represent the full range of observed sediment bed elevation changes over time. Further discussion of these issues is presented in Section 5.

## TABLE 4-5 COMPARISON OF SEDIMENT BED ELEVATION CHANGES

| Station (Agency) | Time Period | Observed (cm) | Model (cm)[12] |
|---|---|---|---|
| T10 (USEPA) | May 1994 to November 1994<br>November 1994 to August 1995 | -9<br>-5 | -0.09<br>+0.01 |
| 370+00 - 360+00 (USACE) | 1990 to 1993<br>1993 to 1997 | -3.5<br>-15 | -1.26<br>-0.11 |
| T9 (USEPA) | May 1994 to November 1994<br>November 1994 to August 1995 | +10<br>-6 | +0.31<br>-0.27 |
| 205+00 (USACE) | 1990 to 1993<br>1993 to 1997 | -7<br>-26 | -0.74<br>~0 (-0.002) |
| T5 (USEPA) | May 1994 to July 1994<br>July 1994 to November 1994<br>November 1994 to August 1995 | +1<br>-7<br>+19 | -0.02<br>+0.04<br>-0.06 |
| 91+00 (USACE) | 1990 to 1993<br>1993 to 1997 | +5<br>+2 | +1.3<br>+0.62 |
| 61+00 (USACE) | 1990 to 1993<br>1993 to 1997 | +5<br>+7 | +7.0<br>+2.8 |
| T3 (USEPA) | May 1994 to September 1994<br>September 1994 to November 1994<br>November 1994 to August 1995 | +72<br>-94<br>+14 | +0.26<br>+0.03<br>+1.04 |

### *4.2.2.2 Net Burial Rate Comparisons*

Cumulative performance comparisons of estimated and inferred net burial rates and model results were developed. One net burial rate value was estimated from results of the 1997-1999 USACE hydrographic surveys of the River navigation channel between the De Pere and Fort James (Georgia Pacific) turning basins. As noted in Section 4.2.2.1, in this section of the River, a 0.7 cm increase in average sediment bed elevations occurred over a two year period. This corresponds to an estimated net burial rate of +0.35 cm/year. A second net burial rate value was inferred from the depth of maximum PCB concentrations in River sediment samples collected in 1995 between De Pere and Green Bay. Based on TM2d (WDNR, 1999a) the year of peak PCB loads to the River was 1969. Based on the 1995 samples, the average depth to maximum PCB concentrations was 24 to 56 cm below the sediment-water interface. This corresponds to an inferred average net burial rate of approximately 1-2 cm/year for the period 1969-1995. However, also as described in TM2d, it is important to note that most of the PCB discharge to the River occurred prior to the implementation of present-day wastewater treatment practices. During the period of peak PCB discharges, loads of point source solids that delivered PCBs to the River were much larger than contemporary loads. Further, the settling characteristics of the particles comprising those loads were substantially different (i.e. untreated versus treated wastes). Consequently the net burial rate of PCBs was likely very high in the past and much smaller in recent years. When adjusted for the changing magnitude and characteristics of point source solids and indexed to the 1989-1995 period, the inferred average net burial rate is approximately 0.2 to 1.4 cm/year (WDNR, 2001b). Comparisons of net burial rates are presented in Table 4-6.

[12] Model results are computed through 1995. Comparisons to observed values through 1997 are qualitative.

## TABLE 4-6 COMPARISON OF NET BURIAL RATES

| Reach | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| Range of Estimates/Inferences | +0.35 cm/year (estimated from observed bed elevations changes USACE 1997-1999)<br>+0.21 to + 0.42 cm/year (estimated from loads and sediment trap efficiencies)<br>+0.2 to +1.4 cm/year (inferred from PCB depth in sediment, indexed to 1989-1995) | | | | |
| Model | +0.43 cm/year | -0.03 cm/year | +0.25 cm/year | +0.12 cm/year | +0.22 cm/year |

In general, model results are within the range of estimated and inferred net burial rates. Note that results for Reach 2 differ the most from the estimated and inferred net burial rates. Reach 2 is narrow and fast moving compared to other sections of the River. Therefore, the near zero net burial rate (in fact a small net scour rate) for this reach is an expected result. However, further performance assessments using this metric were difficult to develop for numerous reasons. The estimated and inferred burial rates are based on observations collected between De Pere and Green Bay. As presented in TM2g (WDNR, 1999c), bed elevation changes (and therefore net burial rates) vary widely in space and over time. The estimate rate of +0.35 cm/year was computed for 1997-1999. The rate applicable to 1989-1995 in each reach may be different. Further, even after accounting for differences in point source loads and particle deposition characteristics, the net burial rate inferred from the depths of maximum PCB concentrations in the sediment is based on values for individual locations. At each location, the inferred rate can vary widely. Extrapolations from single locations to broad areas may be inaccurate. Further discussion of these issues is presented in Section 5.

#### *4.2.2.3 Surface Sediment PCB Concentration Trend Comparisons*

Cumulative performance comparisons of inferred annual surface sediment PCB concentration trends and model results were developed for each River reach as well as the whole River. Inferred trends were developed from field observations aggregated to represent the 0-10 cm sediment layer as described in Appendix B and summarized in Section 4.2.2.2. Model results were also aggregated to represent the 0-10 cm layer for each sediment stack (volume-weighted average in the vertical) and then averaged for each reach or the whole River (area-weighted average in the horizontal). Comparisons of annual surface sediment PCB concentration trends are presented in Table 4-7.

Results for Reach 1 agree with the direction of the inferred trend but are smaller in scale. Results for Reach 2 differ in both direction and scale. However, inferred trends over time for these two reaches may actually reflect PCB concentration trends in space due to changes in sampling locations over time. Results for Reach 3 agree with both the direction and scale of the inferred trend and are near zero. This is consistent with the inference that no significant PCB concentration trends over time exist in Reach 3. Results for Reach 4 also agree with the direction of the inferred trend but are slightly larger in scale. Overall model results fall just outside of the lower range of inferred trends.

## TABLE 4-7 COMPARISON OF ANNUAL SURFACE SEDIMENT (0-10 CM) PCB CONCENTRATION TRENDS

| Reach | 1 | 2 | 3 | 4 | All |
|---|---|---|---|---|---|
| Inferred | -11.1% to -37.9% | +15.4% to +84.0% | -25.4% to +6.4% | -8.5% to +9.1% | +0.6% to +13.8% |
| Model | -6.8% | -5.8% | -1.2% | +9.6% | -1.0% |

When considering these comparisons, it is important to recall the numerous caveats associated with inferred surface sediment PCB concentration trends. Apparent trends over time may be strongly influenced by, or reflect, spatial heterogeneity and analytical bias. As a consequence, it is difficult to determine direction or scale of any potential trend from these data. Because apparent trends may really reflect shifts in sampling locations over time or differences in analytical procedures, the uncertainty associated with these trend inferences is very high. As a result, comparisons to these sediment PCB concentrations trend inferences may not indicate the quality of model performance. Further discussion is presented in Section 5.

# 5 DISCUSSION

## 5.1 APPROPRIATENESS OF THE wLFRM FOR USE IN THE RI/FS, THE PROPOSED PLAN, AND ROD

WDNR believes the wLFRM is appropriate for its use within the RI/FS. As described in Sections 2 through 4 of this White Paper, as well as by WDNR (2001a), the Technical Memoranda developed by the Model Evaluation Workgroup, and other supporting documents, the wLFRM successfully represents the observed trends of PCB in the water column and sediment bed of the Lower Fox River. Model parameter values are well within the range of observed values for each transport process in the model. Model performance is also generally within the limits specified by the model evaluation metrics developed in collaboration with the FRG and documented in TM1 (LTI and WDNR, 1998).

Development of the wLFRM is consistent with the information developed by the Workgroup. The wLFRM was developed collaboratively through multiple governmental, university, and industry workgroups. The development history of the model framework and its application to the Lower Fox River has been extensively documented as described in Section 3.1 of this White Paper. In particular, wLFRM was based on the findings of the Model Evaluation Workgroup Technical Memoranda prepared in collaboration with the Fox River Group (FRG) of Companies on the basis of a January 1997 Agreement. The Technical Memoranda define values for critical model features such as flows, loads, initial conditions, boundary conditions, and sediment transport. The Workgroup reports listed in Table 3-1 represent the most detailed description possible of pertinent River conditions using existing data and provided the majority of the information necessary for model development.

Further, development of the wLFRM is consistent with peer-reviewed journal publications and is also consistent with the recommendations of a peer review panel. The wLFRM and IPX 2.7.4 framework have been thoroughly peer reviewed. This includes publication in peer-reviewed journals, peer review and adoption by the EPA (EPA 2001), and by an independent panel. This included the FRG-initiated peer review of model performance that was managed by the American Geological Institute (AGI). To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts.

Note that the wLFRM uses estimates of hydrodynamics (flow velocities), sediment transport (shear stresses, erosion, and deposition), sediment mixing, and PCB transport that are consistent with field observations and other studies of these conditions for all four reaches of the Lower Fox River. Development and calibration of the wLFRM was performed on a reach-by-reach basis. Comparisons of observed conditions and model results were developed for each of the four reaches used in the RI/FS: Little Lake Butte des Morts (Lake Winnebago to Appleton), Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay. In this regard, the wLFRM described PCB transport for each of the four reaches of the River.

Also note that the performance of the wLFRM is consistent with the evaluation metrics developed in collaboration with the FRG. Model performance was evaluated according to the metrics identified in Technical Memorandum 1 (LTI and WDNR, 1998), a collaboratively developed Workgroup product. For the water column, the overall relative difference between observed solids and PCB concentrations and model results was within ±30 percent. While relative differences for the sediment column were much larger, it is important to understand how the observations and model results used to assess model performance were interpreted. Successful application of a given evaluation metric depends on how closely the interpretation of field data represent the true condition of the River as well as whether the spatial and temporal scale of observations and model results are comparable. In this regard, the wLFRM was able to capture the trend and magnitude of inferred PCB concentration trends in surface sediments and net burial rates. Given these considerations, the wLFRM calibration was judged to adequately meet the criteria identified in Technical Memorandum 1.

Finally, the wLFRM accurately represents the most critical features of Lower Fox River Site conditions. As demonstrated by the results of field sampling efforts, the only significant present-day source of PCBs to Lower Fox River is the River sediments. PCB concentrations in River water are essentially zero at the upstream boundary with Lake Winnebago and increase to an average of more than 50 ng/L at the River mouth. The wLFRM reproduces the sediment origin of PCBs as well as the trend and magnitude of PCB concentrations in the water column and sediment.

In consideration of the qualities described above, use of the wLFRM was judged to be appropriate as an indicator of the relative trend and magnitude of PCBs concentrations and export in the Lower Fox River. In this context, the year-by-year, reach-by-reach resolution of this model was considered sufficient to meet overall project goals. In consideration of model performance strengths and limitations, the wLFRM calibration was considered to provide a reasonable description of PCB concentrations and export in the Lower Fox River on a year-by-year, reach-by-reach basis. Given the level of documentation, peer review, consistency with observed conditions in the River, and performance relative to the collaboratively developed model performance metrics, WDNR believes that wLFRM is suitable for its intended use within the RI/FS, the Proposed Plan, and ROD.

## 5.2 RESPONSE TO COMMENTS

As part of the public response to the RI/FS, WDNR and USEPA received comments from the Fox River Group (FRG) of Companies and their consultants that claim the computer modeling supporting the RI/FS and Proposed Plan analysis is flawed. Specifically citing the wLFRM, these commenters argued that the wLFRM:

1. Is not adequately documented or developed;
2. Does not appropriately track sediment PCB concentrations over the calibration period;
3. Overstates the shear stress and amount of resuspension;

4. Does not account for releases of PCBs during dredging; and

5. Does not account for residual PCB concentrations post-dredging.

In addition to these broadly generalized categories of comments, WDNR and USEPA also received specific comments from the FRG, individual FRG companies, and their consultants that were critical of a range of other wLFRM performance issues. Responses to the broad comment categories and specific comments are presented below. In developing responses to comments, the main concern of WDNR and USEPA was whether: (1) information provided would significantly alter the possible range of model parameter values such that the calibrated values used in the wLFRM would be outside the range of acceptable values; (2) proposed alterations to the model formulation are technically sound and would result in a demonstrably superior model and not just simply a different model; and (3) differences in model results would materially affect RI/FS conclusions or the management decisions presented in the Proposed Plan, or ROD.

### 5.2.1 Response to Broadly Generalized Comments Regarding the wLFRM

With respect to the adequacy of model development, note that the wLFRM represents the fourth generation of model development specific to PCB transport in the Lower Fox River. In addition to extending the efforts of three prior generations of development, the wLFRM was itself the result of several years of development efforts that included the direct, collaborative involvement of the FRG and consultants through the Model Evaluation Workgroup. Workgroup findings, presented in numerous Technical Memoranda, provided the basis for nearly all aspects of model development. With respect to the adequacy of model documentation, the RI/FS (RETEC, 2002a, 2002b) and associated Model Documentation Report (WDNR and RETEC, 2002) include all Workgroup Technical Memoranda and reports specific to wLFRM development and calibration, and documentation of the IPX 2.7.4 framework. These reports provide several thousand pages of documentation for the wLFRM. In addition, three peer-reviewed journal publications and numerous other reports provide additional documentation of wLFRM history and development. Given this high level of development and documentation, WDNR believes that claims suggesting that the wLFRM is not adequately developed or documented do not have a sound basis.

With respect to the ability of the wLFRM to appropriately track sediment PCB concentrations during the calibration period, note that simulated reach averaged surface sediment PCB levels in the wLFRM fall within, and never exceed, the 95 percent confidence intervals of observed PCB levels. Considering the area between the De Pere dam and the River mouth (Reach 4), the upper 95 percent confidence limit of the observations is more than 60 percent larger than the average.[13] Model results for Reach 4 never exceed the 95 percent confidence limit of observed PCB levels for this reach. The small (~1 mg/kg) difference in model results over time is more a reflection of the spatial

[13] The average PCB concentration in the 0-10 cm sediment layer of Reach 4 is 4.0 mg/kg. The upper 95 percent confidence limit of the average value is 6.6 mg/kg. Observed concentrations in Reach 4 (232 values) are lognormally distributed. The average and 95 percent confidence limits were computed as from the log-transformed data, detransformed to normal space, and corrected for detransformation bias. The upper 95 percent confidence limit is 64 percent larger than the mean value.

heterogeneity of the observations rather than any failure of the model to appropriately track surface sediment PCB levels. Perhaps more significantly, it should be also be noted that this FRG comment regarding the ability of the a model to track PCB levels is based on the flawed and demonstrably incorrect premise that PCB concentrations in sediments can never increase over time. At any location where PCB levels immediately below the surface-most sediments exceed the PCB levels found in surface sediment, the possibility for PCB increases exists. Any time bed elevation decreases occur at that location, the average PCB concentration in the top 10 cm of sediments will increase. As conclusively demonstrated by Technical Memorandum 2g (WDNR, 1999c) and follow-up efforts, such decreases in sediment bed elevations are common in the Lower Fox River. Given that wLFRM performance falls within the 95 percent confidence limit of the observations and that sediment bed elevations decreases do occur and may cause PCB levels in surface sediments to increase, WDNR believes that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

Further, it must be recognized that the main pathway for risk in the Lower Fox River is PCB exposure via the water column. As part of calibration, PCB levels in the water column and sediment bed were both considered. Once model results for both the water column and sediment bed met the model performance criteria established in Technical Memorandum 1 (LTI and WDNR, 1998), the model calibration was considered acceptable. Despite the greater uncertainty of model results for the sediment column, model performance for sediment PCB levels is nonetheless acceptable. More importantly, model performance for the central risk pathway, water column PCB exposures, is quite good. Again, in light of all these factors, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

With respect to the ability of the wLFRM to represent shear stresses and erosion amounts, it should be noted that these aspects of wLFRM development are based on results of hydrodynamic and sediment transport model developed for the Site as described in Technical Memoranda 5b (Baird, 2000a), 5c (HydroQual, 2000), and 5d (Baird, 2000b). The results of these hydrodynamic and sediment transport models were used to develop the wLFRM. As documented by WDNR (2001a) and as shown in Table 4-1 of this White Paper, the close agreement (17 percent overall difference) between simulated and observed solids levels at each monitoring in the River demonstrates that the wLFRM adequately represents sediment transport in the River. Given this level of agreement, WDNR believes that shear stresses and erosion amounts are appropriately represented in the wLFRM. Further discussion of these issues with respect to specific comments regarding the representation of shears stresses and erosion is presented in Section 5.2.2 of this White Paper.

With respect to the representation of PCB releases during dredging, note the wLFRM represents remediation by a series of alternative-specific targets for post-remediation sediment bed elevations and PCB concentrations initially at depth in the sediment bed. The wLFRM does not explicitly simulate dredging. As discussed in *White Paper No. 9 – Remedial Decision-Making for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision* (WDNR, 2002a), PCB releases during dredging are expected to be very small relative to existing levels of PCB transport in the Lower Fox River. In particular, it should be noted that during the Deposit N and SMU 56/57 demonstration projects, the mass of PCBs released by dredging was roughly two orders of magnitude smaller (less than 1 percent) than the present level of ongoing PCB transport through the Lower Fox River. Assuming full-scale dredging operations were initiated, direct releases of PCBs during dredging (a few kilograms per year) would always be far smaller than natural transport rates (several hundred kilograms per year). Further, as documented by the Sediment Technologies supporting study of the RI/FS (RETEC, 2002a, 2002b), direct PCB releases during dredging can be minimized by the use of careful controls during dredging. Given these observations, the effect of PCB releases during dredging and the impact of PCBs potentially present in post-dredge patina layers were considered negligible.

With respect to the representation of residual surface sediment PCB concentrations immediately following dredging, note the wLFRM represents remediation by a series of alternative-specific targets for post-remediation sediment bed elevations and PCB concentrations. Patinas (thin residual layers) of more-highly PCB-contaminated sediments were not explicitly included in the wLFRM based on consideration of the ability of dredging technologies to achieve low residual PCB concentrations and the rapid rate at which conditions at the sediment-water interface are expected to change following dredging. In particular, as monitored following first phase of the SMU 56/57 demonstration project in 1999, PCB concentrations in portions of the dredged area where post-dredging bed elevation meet the target elevation were approximately equal to PCB concentrations initially present at that sediment depth (WDNR, 2000c). Further, post-dredging monitoring of the SMU 56/57 site showed that rapid changes in the sediment-water interface occurred over time and that conditions a few months following dredging did not resemble conditions immediately following dredging (WDNR, 2002b). Given these observations, the effect of PCB releases during dredging and the impact of PCBs potentially present in post-dredge patina layers were considered negligible.

Finally, it should also be noted that FRG comments regarding PCB releases and residual PCB levels are based on the flawed premise that remediation actions involving dredging must always occur in a manner that causes large PCB releases and that dredging efforts will always fail to achieve the targets set for remediation. As noted above, substantial site-specific information exists to demonstrate that PCB releases during dredging are small and that low residual PCB levels can be achieved. Given this information, WDNR believes that FRG claims regarding PCB releases and residuals are unjustified.

### 5.2.2 Responses to Specific Comments

Responses to specific comments from the FRG, individual FRG companies, and their consultants are presented below. In developing responses to comments, the main concern of WDNR and USEPA was whether: (1) information provided would significantly alter the possible range of model parameter values such that the calibrated values used in the wLFRM would be outside the range of acceptable values; (2) proposed alterations to the model formulation are technically sound and would result in a demonstrably superior model and not just simply a different model; and (3) differences in model results would materially affect RI/FS conclusions or the management decisions presented in the

PROPOSED PLAN or ROD. Where possible, similar comments were grouped and paraphrased to permit presentation of more concise responses.

***Comment:***

The wLFRM prediction of PCB sediment concentrations under the "no action" alternatives does not reflect the strong and continuing downward trend shown by actual sediment data. As a result, the model underestimates the degree to which natural attenuation is occurring.

***Response:***

The claim that strong and continuing downward trends in Lower Fox River sediment PCB levels exist is not supported by observations. Surface sediment PCB trends were examined in two different supporting studies as part of the RI/FS. As documented by Appendix B of WDNR (2001a), no clear trends exist. At different locations, surface sediment PCB levels may appear to increase, decrease, or stay the same. Similar findings were also reported by TMWL (2002). As summarized in Section 2.2 of this White Paper, four conclusions that may be drawn from these data: (1) a spatial trend of generally decreasing sediment PCB concentration with distance from Lake Winnebago exists; (2) apparent PCB concentration changes over time may reflect the spatial heterogeneity of PCBs in the sediments; (3) at any individual location, sediment PCB concentrations may increase, decrease, or stay the same over time; and (4) the overall rate at which surface sediment PCB concentrations change over time is slow. It should also be noted that in attempting to justify their claim, the commenters relied on inappropriate combinations of data. Over time, data were collected at different locations, from different strata, and using different sample collection and analytical protocols. Biases introduced as a result of these methodological differences are more than large enough to account for any trends the commenters inferred. A brief discussion of these biases is provided by WDNR (2001a). In light of the failure of the commenters analyses to even identify, let alone account for, methodological differences, WDNR and EPA believe that the trend assessments that the trends assessments performed as part of the RI/FS are far more reliable.

***Comment:***

Both the ECOM-SED model and the RMA model predict substantially lower shear stress and depths of scour near the banks of the River.

***Response:***

This comment overstates the differences between hydrodynamic model results and conditions in the wLFRM. The wLFRM uses flow-velocity relationships developed from the results of hydrodynamics models to estimate shear stresses and erosions amounts (from which depth of scour is estimated). These flow-velocity relationships relate average hydrodynamic velocities over the surface area of each sediment deposit, interdeposit area, and sediment management unit (SMU) to the average flow. The average value used in the wLFRM will represent the average hydrodynamic value that occurs over any sediment area. It is therefore important to recognize that the hydrodynamic models and the wLFRM have different spatial scales. Within any wLFRM segment, hydrodynamic model results can be somewhat larger or smaller than the average value. However, when hydrodynamic model grid cells within a given wLFRM segment are appropriately averaged, there is a direct correspondence between the hydrodynamic model results and the wLFRM.

ECOM grid cells are much smaller (~60 m by 90 m) than those needed to develop the wLFRM (~400 m by 1,000 m). To make long-term simulations computationally feasible, the wLFRM was developed with a coarser spatial scale than ECOM. ECOM results were averaged over wLFRM water column segments to produce relationship between velocity and average flow. Averaging is also necessary because: (1) flow is the only parameter for which a long-term record exists from which velocity can be estimated; and (2) the long-term flow observations (1954-1995) include conditions which did not occur during the ECOM (TM5b, TM5c) 1989-1995 calibration period. As a result of spatial averaging some fine-scale detail is lost. However, average velocities are preserved. By definition of an average quantity, for each case where the velocities at individual ECOM grid cells are less than the average velocity of a wLFRM segment, there are an equal number of locations were velocities at ECOM grid cells exceed the wLFRM average velocity. Perhaps more importantly, it is worth noting that the purpose of the wLFRM was to provide insight into the relative trends and magnitudes of PCB concentrations over time on a reach-by-reach basis. For this spatial and temporal scale, use of average velocity values is very reasonable. Also, proposed remedial strategies are provided on a reach-by-reach basis. Sediment management on a 60 m by 90 m scale is impracticable. Even if remediation on such a fine scale were practicable, preservation of ECOM (or RMA) results at the full spatial and temporal resolution of the two-dimensional hydrodynamic model is of questionable value. The flow structure of a natural system is three-dimensional as secondary and helicoidal flows and other conditions occur. Vertically averaged, two-dimensional hydrodynamics models do not resolve such flow features (see Lane et al. 1999). Under such conditions, retaining the full precision of a two-dimensional hydrodynamic approximation provides no additional accuracy; representing an approximation with more significant figures does not improve the underlying accuracy of the approximation.

***Comment:***

The wLFRM predicts steady erosion in roughly 20 sediment bed segments in the center navigation channel of the River below the De Pere dam. For decades, it has been necessary for the USACE to dredge this navigation channel to keep the channel open for commercial traffic. Thus, many of the specific areas that wLFRM assumes to be erosional are the same areas the USACE must dredge regularly to remove new deposits.

***Response:***

It is important to note that this comment misrepresents the extent of dredging and locations where dredging has occurs in the Lower Fox River over the past 30 years. The only areas are the navigation channel where dredging has routinely occurred are the Fort James (Georgia Pacific) and East River turning basins. As documented in TM2g (WDNR, 1999c), much of the navigation channel has not been dredged in 30 years. Of those few locations where dredging has occurred, many of those areas have been dredged once. The reason dredging has not occurred in much of the navigation channel is because sediment bed elevations have either been relatively constant or have decreased over time. While observed bed elevations are more dynamic than wLFRM results (or the results of any sediment transport model developed for the Site), the model typically represents the direction of bed elevations changes over time as shown in Table 4-5 of WDNR (2001a) and Section 4.2.2.1 of this White Paper.

***Comment:***

The wLFRM improperly uses a mixing depth of 30 cm, and should instead use a 10-cm mixing depth. The draft Model Documentation Report dated October 2001 does not provide any justification for the assumption of a 30-cm mixing depth. The literature "standard" for mixing is 10 cm and should be used.

***Response:***

As described in Section 2.5 of this White Paper, mixing depths used in the wLFRM are well supported by field data. Observed sediment mixing depths vary widely. While typical mixing depths range from 10 to 30 cm, sediment disturbances of up to 200 cm have been observed. It should be noted that this comment falsely asserts that a "standard" sediment mixing depth exists. This assertion is based on the false premise that mixing is almost exclusively driven by biological processes and other processes do not disturb the sediment bed. However, contrary to this premise, other processes such as bed elevation changes due to flow events, density currents, and sediment slumping can also disturb and mix sediments. As described in TM2g (WDNR, 1999c) and follow-up efforts (WDNR, 2001a), sediment bed elevations in the Lower Fox River are very dynamic. Over monthly to annual times scales, sediment bed elevations have been observed to regularly fluctuate between 10 to 30 cm. Larger fluctuations of approximately 200 cm have also been recorded over annual time scales. Over broad areas, the net change in bed elevation is very small. This means that at each location where a large decrease in bed elevation occurs, there is typically a nearby location with a correspondingly large increase in elevation. Consequently, within the same general area there is a pattern of mixing where particles and contaminants located deeper within the sediment column can return to the sediment surface and materials initially at the surface are buried until the next disturbance occurs. In addition to bed elevation data, the periodic disturbance of sediments to considerable depth in the sediment column is supported by the Cesium-137 (Cs-137) profile results reported by Steuer et al. (1995) that show sediment disturbances to depths of approximately 40 cm. It should also be noted that data provided by the comment documents mixing depths of up to 20 cm from locations where intact Cs-137 profiles could be obtained. Given the large number of observations that indicate sediment mixing depths are variable and that sediment disturbances of up 200 cm can occur, WDNR and EPA believe the claim that sediment mixing depths are limited to 10 cm is not defensible.

***Comment:***

The wLFRM's segmentation of the sediment bed is flawed because initial segment thicknesses in the model vary from 5 cm at the surface to 50 cm at depth. As a result, the mixed depth of sediment increases significantly over time in some areas, exacerbating the effects of the 30-cm mixing depth error. The use of uneven strata makes the wLFRM incapable of accurately reflecting surface sediment concentrations when erosion occurs.

***Response:***

As described in Section 2.5 of this White Paper, the depth to which sediment mixing or other disturbances may occur is not constant and varies widely by location and over time. The most straightforward method to represent variability in the depths of sediment disturbances was the use of sediment segments that increase in thickness with depth below the sediment-water interface. By use of this segmentation approach, the sediment mixing depth in and sediment stack can vary in response to the extent of erosion or deposition that occurred. Areas subject to larger disturbances will take on a larger mixing depth and areas subject to less extensive disturbances will take on a smaller mixing depth. Given the observed extent and variability of sediment mixing depths as summarized by WDNR (2001a), Section 2.5 of this White Paper, and LTI (2002), WDNR and EPA believe that mixing depths are appropriately represented in the wLFRM.

***Comment:***

Application of the wLFRM results in an artificial buildup of PCB mass in the surface sediment layers.

***Response:***

As previously noted, WDNR and EPA believe the commenters have misrepresented the nature of wLFRM results. With respect to the ability of the model to track sediment PCB levels over the calibration period, it is important to note that simulated reach-averaged surface sediment PCB concentrations are within the 95 percent confidence intervals of observed PCB levels. Considering the area between the De Pere dam and the River mouth (Reach 4), the upper 95 percent confidence limit of the observations is more than 60 percent larger than the average as previously noted. Model results for Reach 4 never exceed the 95 percent confidence limit of observed PCB levels for this reach. The small (~1 mg/kg) difference in model results over time, described as an “artificial buildup” by the commenters, is more a reflection of the spatial heterogeneity of the observations rather than any failure of the model to appropriately track surface sediment PCB levels. Because model results do not fall outside the confidence limits of the initial condition, the proper interpretation of wLFRM results is that the model predicts little change in surface sediment PCB levels over time. Such a result and interpretation is consistent with the surface sediment PCB trends analyses presented in the RI/FS.

Perhaps more significantly, note that this comment is based on the flawed premise that PCB levels in sediments can never increase over time. In contrast to this premise, note that at any location where PCB levels immediately below the surface-most sediments exceed the PCB levels found in surface sediment, the possibility for PCB increases exists. Any time bed elevation decreases occur at that location, the average PCB concentration in the top 10 cm of sediments will increase. As conclusively demonstrated by Technical Memorandum 2g (WDNR, 1999c) and follow-up efforts, such decreases in sediment bed elevations are common in the Lower Fox River. Given that wLFRM performance falls within the 95 percent confidence limit of the observations and that sediment bed elevations decreases do occur and may cause PCB levels in surface sediments to increase, WDNR and USEPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

Further, it must again be recognized that the main pathway for risk in the Lower Fox River is PCB exposure via the water column. As part of model calibration, both the water column and sediment bed were considered. Once model results for water and sediment met the model performance criteria established in Technical Memorandum 1 (LTI and WDNR, 1998), the model calibration was considered acceptable. Despite the greater uncertainty of model results for the sediment column, model performance for sediment PCB levels is nonetheless acceptable. More importantly, model performance for the central risk pathway, water column PCB exposures, is quite good. Again, in light of all these factors, WDNR and EPA believe that claims suggesting the wLFRM does not appropriately track sediment PCB levels are unsupported.

***Comment:***

The wLFRM does not adequately represent the relationship between sediment volumes and exchange areas in subsurface sediment layers. They content that this leads to greater rates of erosion in some areas.

***Response:***

This comment is incorrect and entirely mischaracterizes the operation of the IPX 2.7.4 modeling framework and the performance of the wLFRM. Surface areas for all sediment layers in the wLFRM vary as determined from field data. As erosion and deposition occur during a simulation, the IPX 2.7.4 framework always uses the appropriate surface area of the sediment segment to compute the mass flux of material to or from each sediment segment. The IPX 2.7.4 framework appropriately manages sediment surface areas (and all other properties) regardless of whether erosion or deposition occurs in a segment. Management of sediment stack properties within IPX 2.7.4 is performed in Subroutines PUSH and POP. Sections 1.5.3.2 and 1.5.4.2 of the IPX 2.7.4 user's manual (USEPA, 2001) describe the operation of these subroutines. Further, examination of model source code for these two subroutines shows that sediment properties are appropriately managed. Therefore, the claim that the relationships between sediment segment volumes and surface areas are not properly represented in the wLFRM is false.

***Comment:***

The wLFRM does not include any modeling process to account for pore water diffusion.

***Response:***

Porewater diffusion is one of the possible mass transfer pathways for PCBs in the sediments. This process is included in the conceptual model framework as described by WDNR (2001) [the wLFRM report in the MDR]. Porewater transfers can move dissolved PCBs between sediment layers and to the water column. In the wLFRM, PCB porewater transfer functions were specified between layers in the sediment column. However, due to an oversight when the model input data files were constructed, the final linkage between the surface sediments and the water column was not specified. Note that porewater diffusion can only transport dissolved and bound phase PCBs. Also note that PCBs are strongly associated with particles because they are hydrophobic and that less than 1 percent of the PCBs in the sediments are expected to be associated with dissolved and bound phases. As a result, the impact of this oversight is expected to be very small.

***Comment:***

The wLFRM should have accounted for dredging processes, including PCB remobilization during dredging, and residual PCB concentrations post-dredging. The FS modeling forecasts of dredge scenarios assumed PCB releases during dredging to be zero, which then results in overestimating removal relative to Monitored Natural recover (MNR). In addition, the wLFRM should have explicitly accounted for post-dredging PCB sediment concentrations.

***Response:***

With respect to the representation of PCB releases during dredging, note the wLFRM represents remediation by a series of alternative-specific post-remediation sediment bed elevations and PCB concentrations initially at depth in the sediment bed. The wLFRM does not explicitly simulate dredging. As discussed in *White Paper No. 9 – Remedial Decision-Making for the Lower Fox River/Green Bay Remedial Investigation, Feasibility Study, Proposed Remedial Action Plan, and Record of Decision* (WDNR, 2002a), PCB releases during dredging are expected to be very small relative to existing levels of PCB transport in the Lower Fox River. In particular, it should be noted that during the Deposit N and SMU 56/57 demonstration projects, the mass of PCBs released by dredging was roughly two orders of magnitude smaller (less than 1 percent) than the present level of ongoing PCB transport through the Lower Fox River. Assuming full-scale dredging operations were initiated, direct releases of PCBs during dredging (a few kilograms per year) would always be far smaller than natural transport rates (several hundred kilograms per year). Further, as documented by the Sediment Technologies supporting study of the RI/FS (RETEC, 2002a, 2002b), direct PCB releases during dredging can be minimized by the use of careful controls during dredging. Given these observations, the effect of PCB releases during dredging were considered negligible.

With respect to the representation of residual surface sediment PCB concentrations immediately following dredging, again note the wLFRM represents remediation as a series of alternative-specific post-remediation sediment bed elevations and PCB concentrations. Patinas (thin residual layers) of more-highly PCB-contaminated sediments were not explicitly included in the wLFRM based on consideration of the ability of dredging technologies to achieve low residual PCB concentrations and the rapid rate at which conditions at the sediment-water interface are expected to change following dredging. In particular, as monitored following first phase of the SMU 56/57 demonstration project in 1999, PCB concentrations in portions of the dredged area where post-dredging bed elevation meet the target elevation were approximately equal to PCB concentrations initially present at that sediment depth (WDNR, 2000c). Further, post-dredging monitoring of the SMU 56/57 site showed that rapid changes in the sediment-water interface occurred over time and that conditions a few months following dredging did not resemble conditions immediately following dredging (WDNR, 2002b). Given these observations, the effect of PCB releases during dredging and the impact of PCBs potentially present in post-dredge patina layers were considered negligible.

In consideration of the monitoring results obtained during Lower Fox River demonstration projects, and the rapid change of Site conditions following remediation, WDNR and EPA believe that the representation if remediation is appropriate to permit the evaluation of relative differences between management alternatives in the RI/FS, Proposed Plan, and Record of Decision.

# 6 CONCLUSIONS

The following conclusions regarding wLFRM development and performance are offered:

1. Development of the wLFRM is consistent with the information developed by the Model Evaluation Workgroup (Workgroup). The wLFRM was developed collaboratively through multiple governmental, university, and industry workgroups. The development history of the model framework and its application to the Lower Fox River has been extensively documented. The wLFRM in particular was developed from the results of the Workgroup formed in collaboration with the Fox River Group (FRG) of Companies on the basis of a January 1997 Agreement. The Workgroup prepared a series of reports that define values for critical model features such as flows, loads, initial conditions, boundary conditions, and sediment transport. The Workgroup reports listed in Table 3-1 represent the most detailed description possible of pertinent River conditions using existing data and provided the majority of the information necessary for model development.

2. Development of the wLFRM is consistent with peer-reviewed journal publications and is also consistent with the recommendations of a peer review panel. The wLFRM and IPX 2.7.4 framework have been thoroughly peer reviewed. This includes publication in peer-reviewed journals, peer review and adoption by the EPA (EPA 2001), and by an independent panel. This included the FRG-initiated peer review of model performance that was managed by the American Geological Institute (AGI). To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts. In addition to these publications, the wLFRM is consistent with AGI peer review panel recommendations that the model: (1) use a single spatial domain to describe PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the River mouth at Green Bay; (2) avoid "deep mixing" of sediment by using the IPX 2.7.4 framework (USEPA, 2001); and (3) simulate solids as (at least) three state variables.

3. The wLFRM uses estimates of hydrodynamics (flow velocities), sediment transport (shear stresses, erosion, and deposition), sediment mixing, and PCB transport that are consistent with field observations and other studies of these conditions for all four reaches of the Lower Fox River. Model development and calibration of the wLFRM was performed on a reach-by-reach basis. Comparisons of observed conditions and model results were developed for each of the four reaches used in the RI/FS: Little Lake Butte des Morts (Lake Winnebago to Appleton), Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay.

4. The performance of the wLFRM is consistent with the evaluation metrics developed in collaboration with the FRG. Model performance was evaluated according to the metrics identified in Technical Memorandum 1 (LTI and WDNR,

1998), a collaboratively developed Workgroup product. For the water column, the overall relative difference between observed solids and PCB concentrations and model results was within ±30 percent. Relative differences for the sediment column were much larger. However, when making comparisons, it is important to understand how the observations and model results used to assess model performance were interpreted. Successful application of a given evaluation metric depends on how closely the interpretation of field data represent the true condition of the River as well as whether the spatial and temporal scale of observations and model results are comparable. In this regard, the wLFRM was able to capture the trend and magnitude of inferred PCB concentration trends in surface sediments and net burial rates. Given these considerations, the wLFRM calibration was judged to adequately meet the criteria identified in Technical Memorandum 1.

5. The wLFRM accurately represents the most critical features of Lower Fox River Site conditions. To accurately represent the Site, a model must agree with observations that demonstrate the origin of PCBs from River sediments and the general trend and magnitude of PCB concentrations in River water. As demonstrated by the results of field sampling efforts, the only significant present-day source of PCBs to Lower Fox River is the River sediments. PCB concentrations in River water are essentially zero at the upstream boundary with Lake Winnebago and increase to an average of more than 50 ng/L at the River mouth. The wLFRM reproduces the sediment origin of PCBs as well as the trend and magnitude of PCB concentrations in the water column and sediment.

6. The use of the wLFRM was judged to be appropriate as an indicator of the relative trend and magnitude of PCBs concentrations and export. In this context, the year-by-year, reach-by-reach resolution of this model was considered sufficient to meet overall project goals. In consideration of model performance strengths and limitations, the wLFRM calibration was considered to provide a reasonable description of PCB concentrations and export in the Lower Fox River on a year-by-year, reach-by-reach basis. Given the level of documentation, peer review, consistency with observed conditions in the River, and performance relative to the collaboratively developed model performance metrics, WDNR believes that wLFRM is suitable for its intended use within the RI/FS and as a tool to support the selection of a remedy in the ROD.

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# WHITE PAPER NO. 17 – FINANCIAL ASSESSMENT OF THE FOX RIVER GROUP

***Response to***

## COMMENTS BY THE FOX RIVER GROUP FOR THE FOX RIVER NRDA SITE, NO. A565


***This Document has been Prepared by***

United States Environmental Protection Agency

Region 5

Superfund Division

Chicago, Illinois  60604


**December 2002**

# WHITE PAPER NO. 17 – FINANCIAL ASSESSMENT OF THE FOX RIVER GROUP

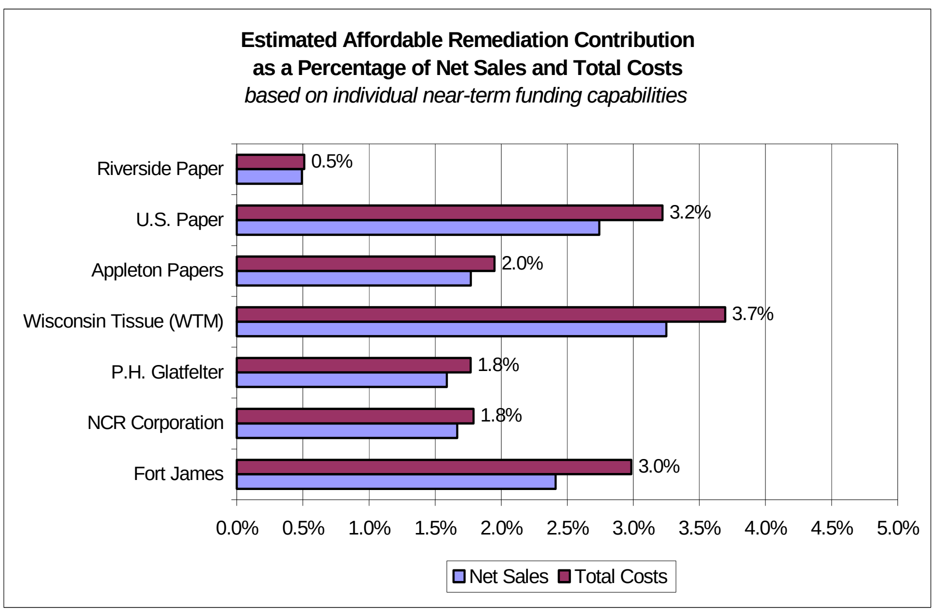
## ABSTRACT


As required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Agencies are required to evaluate the financial impact of the Record of Decision. This White Paper provides a financial assessment of the Fox River Group (FRG) by presenting:

- The remedial activity contribution burden for each company within the FRG;
- The estimated remediation contribution as a percentage of net sales;
- How the financial contributions will contribute to operating costs;
- An industrial analysis of changes in the paper and paperboard commodities;
- The financial resources currently available to the FRG; and
- The consolidation and merger activity within the FRG.

Based upon these analyses the following was concluded; that the cost of remediation will result in limited financial burden to the companies of the Fox River Group; that the paper and paperboard future is bright; that except for Riverside Paper, the Fox River Group are in sound financial health; and finally that consolidation should provide relief to the remaining paper producers on the Lower Fox River.


## ASSESSMENT




- The members of the Fox River Group range from large, multi-national corporations to relatively small, privately held businesses. The table above illustrates the contribution burden for each company based on a remediation cost estimate of $307 million. The underlying contribution amount, or "near-term funding capability," was developed based on an extensive financial and economic analysis of each company and the broader paper products industry. The near-term funding capability represents the amount of funds each company could apply toward remediation in the next 2 to 3 years.

- The estimated remediation contribution as a percentage of net sales and total costs is relatively consistent across the seven companies. The exceptions are U.S. Paper Mills, Wisconsin Tissue, and Fort James. The estimated contribution for these companies is slightly higher on a relative basis (averaging 3.3 percent of total costs), due to their superior financial performance in recent fiscal periods. We note that over the past 18 months, all three companies were purchased by large, multinational corporations with total annual 2001 sales revenue of approximately $31 billion. In our opinion, the acquisitions should bolster the financial health of Fort James, U.S. Paper Mills, and Wisconsin Tissue.

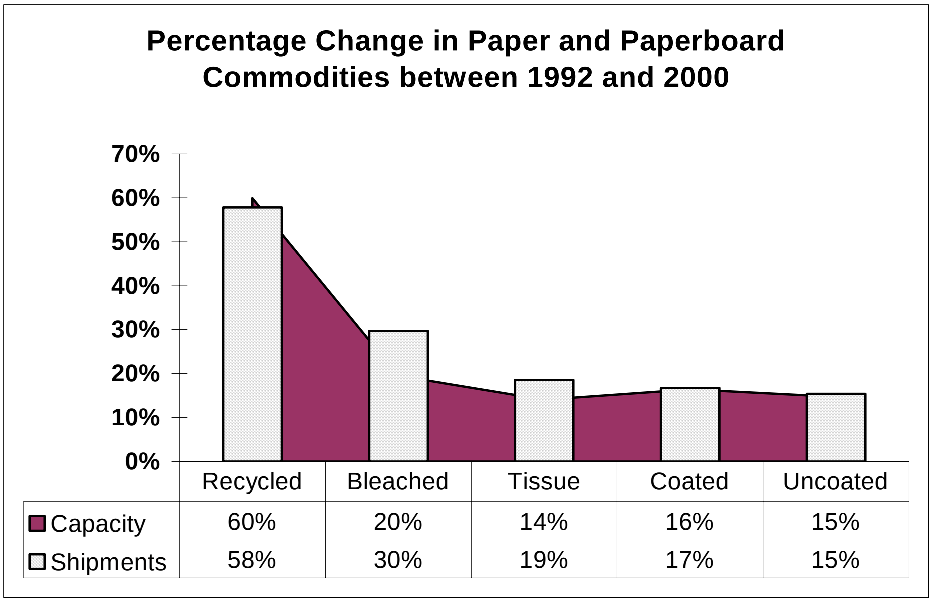
- Conversely, Riverside Paper's declining performance in recent fiscal periods and overall financial condition contributes to a relatively low contribution as a percentage of net sales revenue and total costs (0.5 percent).

- In terms of potential impacts, it is likely that contributing to the cleanup of the Lower Fox River Site will result in higher operating expenses for the seven companies. However, the degree to which producers are able to pass these added costs through to customers in the form of increased product prices will dictate whether (and by how much) corporate profits suffer.

- Our analysis indicates that the cost of remediation (adjusted for each member's near-term funding capability) will result in limited financial burden for the Fox River Group. The companies are large enough and healthy enough to manage payments of this magnitude, particularly if the resources of their corporate parents are considered. We also note that we consider funding capabilities over the near-term, while the Lower Fox River remediation will occur over a longer time period.

## INDUSTRY ANALYSIS

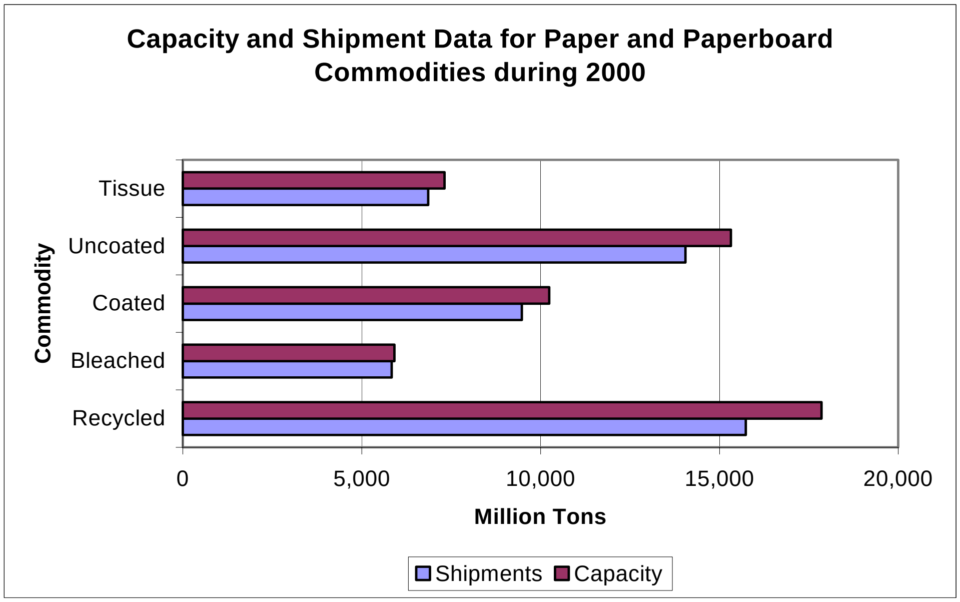
- The domestic paper and allied products industry is characterized by considerable competition. Through 2001, companies continued to use mergers and acquisitions as a means of increasing market share and reducing production costs. For example, in many cases, it is cheaper to purchase existing capacity than to build new capacity.




- The trend toward consolidation likely will continue in the near term as large, financially secure corporations seek to buy (and retire) excess capacity. The respective acquisitions of Fort James and U.S. Paper Mills by Georgia-Pacific and Sonoco Products represent two such recent examples.

- By our calculations, recycled and bleached paperboard represent the largest increases in capacity and related shipments between 1992 and 2000. This sector of the paper and allied products industry (with end uses including folding box board, writing tablets, and folding cartons) continues its transformation from a regional to a global commodity.

- Continued development of new consumer products that require folding cartons will contribute to continued strong demand for recycled and bleach paperboard in the near term.

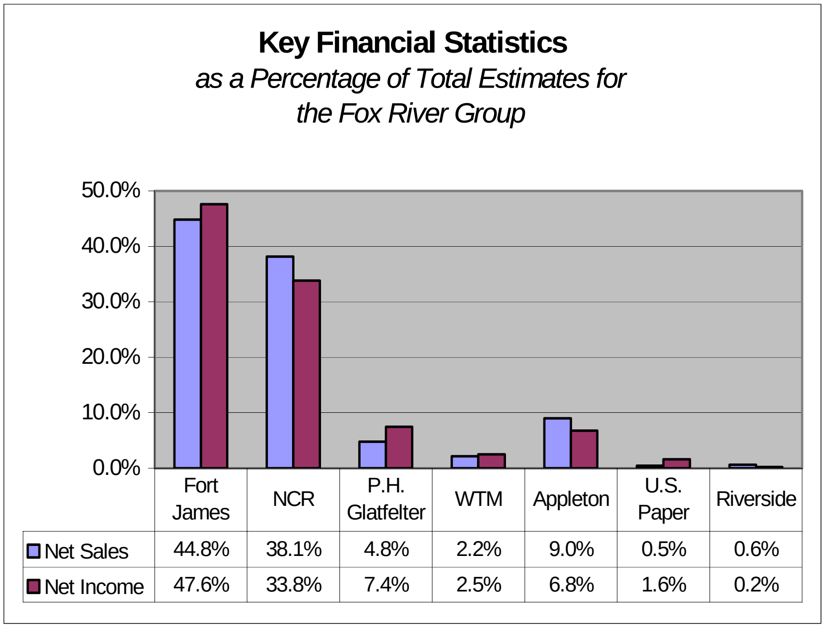



- North American producers sought to restrain capacity and match output to demand using a just-in-time approach in 2000. Although producers were better able to clear excess inventory, excess capacity remains in the uncoated paper and recycled paperboard sectors.

## The Financial Resources of the Fox River Group

- The members of the Fox River Group experienced varied financial performance in recent fiscal periods. Much of this fluctuation mirrors the cyclical nature of the paper and allied products industry.

- Based on a review of key financial metrics, including the profitability, liquidity, and solvency of each company, we identified the strengths and weaknesses of each company's financial position. Our analysis reveals that U.S. Paper and Fort James receive the highest performance scores; Riverside Paper receives the lowest score.




- In terms of overall performance, Fort James and NCR Corporation represent the strongest members relative to other Fox River Group companies. Respectively, these companies account for 45 percent and 38 percent of net sales generated by the Fox River Group during the most recent fiscal periods for which we have data.

- Analysis indicates that Fox River Group companies continue to benefit from reasonably healthy consumer demand with only moderate increases in raw material costs.

- In fact, many of the larger producers successfully passed increases in raw material costs through to their consumers, contributing to relatively healthy free cash flow during 2000 and 2001.

- With the possible exception of Riverside Papers, the member companies of the Fox River Group appear to be in sound financial health.

## CONSOLIDATION AND MERGER ACTIVITY

- Global competition is forcing aggressive streamlining and consolidation within the paper and allied products industry. Consolidation should provide relief to the producers that remain.

- Four members of the Fox River Group – Fort James, Appleton Papers, U.S. Paper, Wisconsin Tissue – experienced significant changes in ownership structure over the past 18 months.

- The degree to which restructuring efforts result in cost savings and revenue growth will bolster the capability of the Fox River Group to fund cost recovery in the near term.

- We recognize that if newly acquired (or existing) mills are unable to perform efficiently, there is an increased possibility that the parents will prune the mills from their asset portfolios.

- Moreover, we are aware of the possibility that large conglomerates (Georgia-Pacific, Sonoco Products, SCA Sweden) may be focused on buying up (and retiring) excess capacity.

**Fort James Corporation**, recently purchased by Georgia Pacific for an estimated $11 billion

**U.S. Paper Mills**, recently purchased by Sonoco Products for an estimated $70 million.

**Wisconsin Tissue**, recently purchased by SCA Tissue North America for $850 million.

**Appleton Papers**, recently subject to an employee buy out valued at $810 million