Hudson River PCBs Site
EPA Phase 1 Evaluation Report

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and
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EPA Phase 1 Evaluation Report

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ACRONYMS

Acronyms

BMP	Baseline Monitoring Program
CAs	Compliant Areas
CAMs	Corrective Action Memorandums
CDE	Critical Design Elements
cfs	Cubic Feet per Second
CU	Certification Unit
CY	Cubic Yard
DEIR	Data Evaluation and Interpretation Report
DoC	Depth of Contamination
DOC	Dissolved Organic Carbon
DQO	Data Quality Objectives
DRET	Dredge Elutriate Test
EGIA	East Griffin Island Area
EPA	Environmental Protection Agency
fps	Feet per Second
FS	Feasibility Study
g/day	Grams per Day
GE	General Electric
g/m^3	Grams per Cubic Meter
GPM	Gallons per Minute
GPS	Global Positioning System
hp	Horsepower
HSD	Tukey-Kramer Honestly Significant Difference
IDW	Inverse Distance Weighting
kg	Kilogram
kg/year	Kilograms per Year
LCS	Laboratory Control Sample
m	Meter
MCL	Maximum Contaminant Level
MDL	Method Detection Limits
mgd	Million Gallons per Day
mg/kg	Milligrams per Kilogram
mGBM	Modified Green Bay Method
mg/L	Milligrams per Liter

MNR	Monitored Natural Restoration
MSL	Mean Sea Level
NAD	North American Datum
NAVD	North American Vertical Datum
NCA	Non-Compliant Area
NEA	Northeast Analytical, Incorporated
ng/L	Nanograms per Liter
NTIP	Northern Thompson Island Pool
NTU	Nephelometric Turbidity Units
NYSCC	New York State Canal Corporation
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
PCB	Polychlorinated Biphenyls
PLs	Prediction Limits
POC	Particulate Organic Carbon
PSCP	Performance Standards Compliance Plan
QAPP	Quality Assurance Project Plan
RAM	Remedial Action Monitoring
RI	Remedial Investigation
RL	Reporting Limit
RM	River Mile
ROD	Record of Decision
RTK	Real-Time Kinematic
SAV	Submerged Aquatic Vegetation
SLC	Shoreline Cores
sq. ft.	Square Feet
SRC	Sediment Residual Cores
SSAP	Sediment Sampling and Analysis Program
TCL	Target Compound List
TID	Thompson Island Dam
TIN	Triangular Irregular Network
TOT	Time of Travel
TPCB	Total Polychlorinated Biphenyl
Tri+ PCB	Polychlorinated Biphenyls containing three chlorine molecules
TSS	Total Suspended Solids

UCL	Upper Confidence Limit
μg/L	Micrograms per Liter
USACE	United States Army Corps of Engineers
USDC	United States District Court
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQ	Water Quality
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

EPA Phase 1 Evaluation Report

EXECUTIVE SUMMARY

Overview

In February 2002, EPA issued a Record of Decision (ROD) for the Hudson River PCBs Site, which called for environmental dredging targeting approximately 2.65 million cubic yards (CY) of PCB-contaminated sediment. The ROD stipulated that dredging will be conducted in two phases. Phase 1 was to be implemented initially at less than full-scale, and was to include an extensive monitoring program. Phase 2 is the remainder of the project, which is to be conducted at full-scale. In selecting the remedy, EPA required establishment of performance standards for resuspension, residuals, and productivity, together called "Engineering Performance Standards for Dredging." These performance standards are designed to promote accountability and ensure that the cleanup meets the human health and environmental protection objectives set forth in the ROD. The final peer-reviewed standards were published in April 2004.

The ROD states that dredging equipment and methods of operation were to be selected based on their expected ability to meet the performance standards. The data gathered during Phase 1 were expected to enable EPA to determine if adjustments are needed to operations in Phase 2 or to the performance standards. The ROD also states that EPA will continue to monitor, evaluate performance data and make necessary adjustments during the full-scale remedial dredging in Phase 2. Thus, the purpose of Phase 1 was to begin the project, providing a "shakedown" period during which the various operations are initiated and evaluated. It was not expected that every detail would go according to plan during Phase 1; rather the experiences are the source of learning to refine later efforts. Some problems were identified during the implementation of Phase 1. Most of these problems are not related to the standards themselves, but represent issues with design and implementation. Improvements can be made based on the experiences from Phase 1 that, along with certain changes to the standards, will further the success of the project in Phase 2.

General Electric Company (GE) implemented Phase 1 based on the requirements of the ROD and the 2006 Consent Decree. This report evaluates Phase 1 operations relevant to the issues in the charge to the independent peer review panel that will evaluate this report and the similar report prepared separately by GE. The peer review panel has been given a set of charge questions to address in their review of the documents. In summary, the charge questions address whether the Engineering Performance Standards can be met individually and simultaneously during Phase 2 of the dredging project, with consideration of any proposed modifications to the Standards. Some of the matters and issues discussed in this report and its appendices are beyond the scope of the peer review. EPA has included such material in the report to inform the public and provide background and contextual information for the Peer Review Panel.

A high-profile project: The Hudson River PCBs Superfund site cleanup is among the largest sediment remedies performed to date. This project is the first sediment remediation project where EPA has required and implemented performance standards as a basis to assess the success of the project construction phase (*i.e.*, the dredging). Further, no dredging project that was undertaken before the Hudson River PCB Superfund site cleanup has been so highly monitored or scrutinized. The experience from the implementation of Phase 1 provides many opportunities to learn lessons applicable to Phase 2 and to other sediment remediation projects.

Phase 1 had many successes: Three significant guideposts for success during Phase 1 were achieved. These are:

1. Both the sediment volume and the PCB mass removed in Phase 1 met or exceeded the amounts initially estimated for the Phase 1 portion of this project. Eighteen Certification Units (CUs) were planned to be dredged during Phase 1, but ultimately 10 were actually dredged (48.3 acres out of 88 acres). The dredging of these 10 CUs resulted in the removal of a greater volume of sediment (284,000 CY[1]) than EPA had planned to remove from all 18 Phase 1 CUs (265,000 CY), exceeding the Productivity Standard requirements for the year. The mass of PCBs removed was equivalent to the planned mass of 20,000 kg for all 18 planned Phase 1 CUs, but represented an 80 percent increase over what was expected for the 10 CUs dredged (11,000 kg).

2. There were few shut-downs due to exceedances of the Resuspension Standard, with limited impact on dredging productivity. Fish tissue impacts were limited to within 2 to 3 miles downstream of the Thompson Island Pool, and the data do not indicate any measurable impacts to fish or water quality in the Lower River.

3. Seventy five percent of the adjusted area (which excludes structure and shoreline setbacks) was completed and closed in compliance with the Residuals Standard, although it was necessary to cap portions of several CUs out of compliance with the Residuals Standard due to schedule constraints (approximately 25 percent of the adjusted area). The residuals standard proved to be an effective tool to identify and manage previously uncharacterized inventory.

These successes were achieved despite multiple complications experienced during the Phase 1 effort, including an inaccurate estimate of the depth of contamination (DoC), extensive wood debris, high river flows, shallow navigation channels, and limitations to dredged sediment transport and processing. As lessons learned in Phase 1 are considered in refining the design for Phase 2, significant improvements to operational efficiencies should be expected, thereby enabling the performance standards to be met consistently and simultaneously. A tabulation of

[1] The number cited here is GE's estimate of the volume. EPA's estimate of the volume is 274,000 CY which represents a minor difference in the way it was estimated.

important findings related to implementation of each of the Performance Standards is presented at the end of this Executive Summary.

Problems with compliance in Phase 1: Due to imprecise estimates of DoC, the first dredging passes collectively succeeded in removing only 49 percent of the total inventory by volume and only 58 percent of total inventory by mass. As a result, dredging of contaminated sediment inventory (as distinguished from residuals) represented about 50 percent of the area dredged during the second and third dredging passes as well. That is not the way the dredging was intended to work. The Residuals Standard assumed that only a small fraction of the area dredged would require inventory dredging after the first dredging pass. Because at least two cuts (or lifts) with the dredging bucket were done at each location for each dredging pass,[2] the inability to capture the full depth of contaminated sediment on the first pass meant that many more dredging cuts were made than necessary, resulting in more resuspension.

The dredging in Phase 1 released about 440 kg of Total PCB as measured at Thompson Island, exceeding the Phase 1 Total PCB mass load criteria of 117 kg. The measured loads at the Schuylerville and Waterford stations were significantly reduced but still exceeded the Phase 1 load criteria. However, the load at Waterford, 151 kg Total PCB, did not exceed 1 percent of the mass removed, which was an important factor underpinning the load criteria.

Despite exceeding the load standard, the PCB concentrations of river water at Thompson Island only exceeded the federal maximum contaminant level (MCL) for drinking water of 500 ng/l on three occasions. Although these exceedances were not confirmed (*i.e.*, not reproduced) by the next day's sampling, EPA chose to halt dredging temporarily to ensure that these concentrations would not arrive at downstream public water intakes.[3] EPA's conservative approach took into account the uncertainties in the highly variable data for the upstream river water time-composite samples. According to GE's estimates, these temporary work stoppages consumed less than 6 percent of the available dredging hours and did not have a major impact on the ability to meet the Productivity Standard.

A one-month maximum production rate of 89,000 CY was planned; however, it was not met. The maximum one-month productivity of about 78,000 CY, based on GE's records, was attained from early July through early August.

Observation of dredging-related impacts: The data do not demonstrate that the dredging led to significant redistribution of contaminated sediments to non-dredged areas. However, limited investigations into such redistribution and settling were not properly executed by GE. While sediment trap data showed elevated PCB concentrations in the vicinity of dredging operations,

[2] It is important to note that in this project, "dredging pass" refers to dredging to the designed dredge prism limits, and can include multiple dredging cuts at one location.
[3] Note, in any case, that the downstream Upper Hudson public water intakes, located at Waterford and Halfmoon, were not in use at that time, as those communities were obtaining their drinking water from an alternate source.

significant settling of PCB-contaminated sediment was not clearly demonstrated. If redistributed sediments were settling out of the water column, they would do so first in the hole left behind by the dredge. However, empirical evidence from CU closure documentation showed that locations within CUs after dredging had limited residuals in many places once inventory was removed, implying that little sediment had re-deposited.

Some increases in fish tissue PCB levels were seen in 2009 when compared to baseline data in the Thompson Island Pool, with limited evidence of responses downstream. There were no increases in fish tissue PCBs below river mile 180 near Schuylerville. EPA expected short-term increases in fish tissue PCBs during the project. EPA also expects that the levels of PCBs in fish will return to baseline conditions relatively quickly following the cessation of dredging, as was observed after the Allen Mill event (a release of PCB-bearing oil originating at Hudson Falls in 1991), and will continue to decline further toward the ultimate remedial goal for fish tissue (0.05 mg/kg wet weight).

Water column concentrations in the Lower Hudson River did not increase in response to loads from the Upper Hudson. In particular, there were no discernable increases in Total PCB or Tri+ PCB[4] at the Lower Hudson monitoring locations near Poughkeepsie, Port Ewen or Rhinebeck. Tri+ PCB concentrations were also unchanged at the Albany monitoring station, roughly 15 miles downstream of Waterford. Further, there were no statistically significant increases in fish tissue PCBs at the Albany/Troy monitoring station below the Federal Dam at Troy, the first station in the lower river.

Since the end of all Phase 1 dredging activities, river water concentrations have returned to pre-dredging levels as demonstrated by monitoring results at all far-field stations from Mid-December through February.

Underlying Issues that Need to be Addressed in Phase 2

Depth of Contamination (DoC) was Significantly Underestimated

DoC underestimates resulted in dredging nearly twice the volume planned for the CUs dredged: Additional dredging in the Phase 1 CUs was necessary because the design cut lines underestimated the true DoC. Overall, if design volumes are adjusted for the physical offsets adjacent to structures that were necessary to manage sediments at the shoreline, the amount dredged in the 10 CUs was nearly double the originally planned volume. The primary consequence of the underestimation of the DoC, *i.e.,* additional unplanned dredging, profoundly affected Phase 1 with respect to compliance with all three performance standards. The relevance and consequences of uncertainty in the DoC measurements was a point of disagreement between EPA and GE over the course of the remedial design. In the comments and associated responses that were exchanged between EPA and GE regarding the Intermediate Design Report (IDR) in

[4] Tri+ PCB refers to the sum of the concentrations of homologues with three or more chlorine atoms.

December of 2005, EPA warned GE that the uncertainty at individual core locations, which EPA estimated to be about 1 foot, would outweigh GE's estimate that DoC measured in the cores would be conservative; EPA went on to warn that "underestimating DoC may lead to additional re-dredging to remove inventory."

In light of GE's concerns about cost-effectiveness, EPA took a performance-based approach in approving the Phase 1 design and allowed GE flexibility to manage the uncertainty in DoC through other means as they implemented the project. Phase I results support EPA's warnings regarding DoC, as the average thickness of additional dredging required was greater than 1 foot and was up to 13 feet. This exchange is documented in more detail in EPA's Phase 1 Observations Report provided in Appendix I-H. Underestimation of the DoC resulted in significant re-dredging to remove inventory and not residuals. This also resulted in multiple re-dredging passes which adversely impacted resuspension. Since it is clear that GE considered its design sufficiently robust to deal with DoC uncertainty during implementation, it is not appropriate to consider the consequences of this design flaw as an unexpected impediment to productivity, nor to attribute the need to re-dredge on the Residuals Standard.

Cores were not vertically referenced at collection: The lack of a vertical reference for the sediment cores collected under the Sediment Sampling and Analysis Plan (SSAP) is a limitation that propagated through the rest of the design. The river system is dynamic as demonstrated by a comparison of bathymetric surveys *(i.e.,* river bottom maps) conducted in 2001, 2005 and 2009 which showed surface elevation changes of 2 ft or more in places. This likely exacerbated the impact of underestimated DoC.

Incomplete SSAP cores confounded DoC interpolation: One significant factor in underestimating DoC was the occurrence of incomplete cores used to design the dredging. About 35 percent of the SSAP cores used in the design of Phase 1 did not fully penetrate the PCB-contaminated sediment (*i.e.,* they were 'incomplete'). At these locations, the DoC was estimated through an extrapolation method. The greater uncertainty in these locations was reflected in the greater additional dredging depth at these locations. More than three quarters of the incomplete core locations required more than 12 inches of additional removal. Many of these SSAP cores were incomplete due to refusal during collection. The refusal was likely due to pieces of wood debris in the sediment, masking an extensive inventory of contaminated sediment beneath..

Incomplete post-dredging cores were common: The issue of core completion was not limited to the SSAP program. GE continued to obtain incomplete cores in many CUs during Phase 1. The inability to obtain complete post-dredging cores also made subsequent DoC estimates inadequate for design of the next dredge pass. This occurred because adjustments were not made to the core collection process to reflect field conditions in Phase 1.

Scow Unavailability

Scow capacity was underutilized due to shallow access draft: Large hopper scows (or barges) used for Phase 1 were designed to operate at drafts (*i.e.*, depth of the boat's bottom in the water) of up to about 11 feet. However, the dredging contractor limited the maximum draft to about 8 feet due to concerns about their stability when carrying large volumes of free water removed from the river with the sediment or added to reduce air emissions during loading and transport. Under average loads the draft was around 5 feet. Had all large hopper scows been loaded to a draft of 8 feet before transporting them to the unloading wharf, the number of scows to be unloaded would have been reduced by over one third, and the amount of time lost at the wharf in maneuvering scows could have been similarly reduced.

The water depths in many of the areas dredged during Phase 1 also restricted the draft available to the large hopper scows, particularly in CUs along the east and west side of Rogers Island. Deepening the channel (*i.e.*, access dredging) near CU-1 would have allowed hopper barges to be loaded to a deeper draft, however loaded barges could not exit the channel until after dredging had been substantially completed in CU-2 and CU-3 due to shallow drafts in those CUs. If DoC had been correctly characterized at CU-1 during design, rather than discovered incrementally during dredging operations, the need for access dredging there would have been obvious.

Scow unloading was inefficient because scows were only partially filled: The efficiency of the unloading excavator dropped significantly when the depth of sediment in the barge fell below that required to completely fill its 5 CY bucket. Had all large hopper scows been loaded to a draft of 8 feet, the unloading rate achieved by the excavator would have been substantially higher and the time lost at the dredges awaiting empty scows would have been reduced substantially.

Limited capacity to unload scows and process sediment: The inability of the scow unloading operation to keep pace with dredging was also affected by problems with the equipment used to separate coarser from finer sediment to be dewatered using filter presses. Specifically, the trommel screen (*i.e.,* size separator) could not handle a full, 5-CY bucket of sediment from the unloading excavator. Other operational problems with the trommel screen occurred nearly every week and several problems occurred with the shaker screens. Once dredging began, it was very difficult to make major improvements to the scow unloading system without stopping the operation altogether. However, a number of improvements were made to the unloading and coarse materials separation systems during the project, such as adding a second pump system to remove free water from the scows and adjusting the amount of recycle water supplied to the trommel screen, among others.

Large quantities of clay in some scows also caused difficulties with the operation of sediment separation equipment. This was particularly evident during the last few weeks of dredging as attempts were made to remove a thin layer of contaminated sediment immediately above an uneven clay surface. Although attempts were made to minimize the amount of clay removed, many dredge buckets contained mostly clay. Ultimately, a decision was made to handle the clay separately from other dredged sediment.

Presence of PCB-bearing Oils in the Sediments

PCB-bearing oils were released from the sediments during dredging in several areas. These oils were observed as sheens on the water during oversight and were also sampled and analyzed during Phase 1. However, the oils were not isolated for analysis such that a specific congener pattern could be identified. The presence of free product oil also likely hampered the collection of precise field replicates at the far-field stations during Phase 1. It is believed that the presence of oil was partially responsible for the high degree of variability observed in sample replicates when concentrations of PCBs in river water approached the 500 ng/L threshold. There was little evidence of the presence of such oils prior to the start of dredging during Phase 1; hence the near-field monitoring requirements for the Resuspension Standard focused on the mobilization of suspended solids. In practice, suspended solids did not approach thresholds set in the Resuspension Standard and were well controlled.

Extensive Wood Debris in all CUs

Wood debris, consisting primarily of slab wood from saw mills, was encountered in portions of most CUs dredged during Phase 1 of the project. This material had accumulated over decades behind the former dam at Ft Edward and was released and washed downstream after the dam was removed in the 1970s. The extent of material was so great that it blocked the channel at Ft. Edward and the mouth of the Champlain Canal, necessitating an emergency removal project at that time so that commerce on the canal could continue. It is expected that slab wood debris will continue to be encountered during Phase 2 dredging in the Thompson Island Pool. Wood debris is also known to exist in River Section 2 near the entrance to Lock 6. Whether this debris is also present in any significant amount in River Section 3 is currently unknown.

The presence of wood in the sediment prevented the dredge buckets from closing fully, and time was lost as the dredge operator attempted to close the bucket before lifting it from the river bottom. In many instances where slab wood was encountered, complete closure of the bucket could not be achieved and sediment and water drained from the bucket as it was lifted above the water surface. This led to increased PCB resuspension rates and a reduction in the amount of sediment placed in the scow during each bucket cycle.

Presence of Bedrock at or above Dredge Cut Lines

In CUs 2, 5 and 6, shallow bedrock at or above the design surface resulted in bucket refusal. The bedrock surface was uneven, so the full design cut lines could not be reached in some areas. Due to the extent of underlying bedrock, EPA and GE had to work out a separate process for dredging in these areas. After this was resolved, dredging over bedrock areas proceeded expeditiously and the PCB-contaminated sediments were removed in compliance with the Residuals Standard. For example, more than 50 percent of the sediment volume ultimately removed from CU-6 was dredged after the bedrock management scheme was put in place.

Cause and Effect

- The underestimated SSAP DoC resulted in:
    - Multiple bucket cuts and dredge passes, resulting in more resuspension losses (more bucket impacts on river bottom, fewer efficient bucket bites);
    - Multiple dredging passes that were ineffective at removing inventory reduced productivity and consumed an inordinate portion of the dredging season;
    - CUs that were left open for long periods and consequently subject to resuspension; and
    - Multiple cuts (or lifts) per dredging pass in anticipation of reaching an incorrectly estimated DoC.
- Multiple dredging passes to remove inventory meant GE's required tolerance of only 3 inches above or below the estimated DoC led to extensive and unnecessary fine grading by the dredging contractor.
    - Such a tolerance implies a level of precision in the knowledge of the DoC that does not exist, and, given the conditions, may not be possible. Hence multiple dredging passes and frequent need for redefinition of the DoC resulted in multiple events of fine grading at surfaces that were not ready to be closed. This unnecessarily increased resuspension;
    - GE imposed this requirement as a cost-saving measure, to minimize the amount of clean material being dredged. However, on the first dredging pass, only 1 location out of 443 of post-dredging coring locations was non-detect for PCBs and only 50 locations out of 443 (*i.e.*, 11 percent) achieved a concentration less than 1 mg/kg Total PCB. This means that the amount of clean material removed if an overcut had been applied would have been minimal; and
    - GE ultimately achieved its cost-saving goal of minimizing removal of clean material but at the expense of all three standards.
- Scow unavailability limited productivity.
- Presence of PCB-bearing oil in the sediments
    - Resulted in extensive PCB losses not tied to solids releases; and
    - Contributed to water quality issues and load exceedances.

- Extensive wood debris in all CUs prevented bucket closure, resulting in resuspension losses
- Unexpected presence of bedrock and variability of bedrock surfaces
    - Decreased bucket productivity; and
    - Had to be field mapped for accurate identification of overlying inventory.
- Incomplete post-dredging cores
    - Prevented accurate DoC re-characterization; and
    - Led to multiple dredging passes.

Recommendations for Phase 2

Proposed Design and Operational Changes

- The uncertainty in DoC should be addressed by the addition of an overcut of 9 inches to the first dredging pass in each CU as well as any subsequent passes targeting 12 inches or more. This overcut represents setting the dredging cut line to the bottom of the first six-inch core segment (rather than the top) with a Total PCB concentration less than or equal to 1 mg/kg and adding 3 inches for uncertainty in dredging precision. An overcut of 3 inches should be added to subsequent passes targeting 6 inches.
- 3-inch tolerances should only be applied when post-dredging sampling has confirmed that the dredging pass to be undertaken is targeting 6 inches or less (residuals).
- The lack of adequate vertical referencing of sample depths for cores taken during the SSAP is a critical uncertainty that needs to be addressed in the Phase 2 design.
- Scow unavailability needs to be eliminated, possibly by conducting access dredging where necessary, filling scows to the maximum acceptable draft, and enhancing the unloading system (for example, by adding a second unloading station).
- PCB-bearing oil releases should be anticipated and characterized during Phase 2 dredging, and additional measures should be taken to minimize their downstream transport.
- Dredging buckets should be sized and deployed for efficient, controlled cuts on a reduced number of dredging passes. As design refinement addresses the uncertainty in the DoC, the number of dredging passes required to capture inventory should decrease. These factors will allow capturing inventory more efficiently to optimize productivity while minimizing resuspension.

- When wood debris is encountered, dredging should continue until the underlying sediment is uncovered and the area is free of debris.
- There should be better mapping of suspected bedrock areas through probing prior to dredging to supplement SSAP information, and design cut lines should be adjusted as necessary.
- Fully penetrating post-dredging cores should be collected and two segments with Total PCB concentrations less than or equal 1 mg/kg should be used to confirm DoC.

Proposed Changes to the Performance Standards

Table ES-1 presents a summary of the major proposed changes for Phase 2 for each of the three standards, associated numerical criteria, the rationale behind the changes, and expected interactions with the other standards.

Table ES-1. Proposed Changes to the Performance Standards

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
Resuspension			
Adjust the far-field net PCB load standard; adjust the seasonal load and corresponding daily evaluation and control level loads upwards. [EPA will propose specific control and evaluation levels for net load after completing ongoing analyses.]	Total load due to the project: 2000 kg Total PCBs	Based on preliminary findings, a total project net PCB load of 2000 kg Total PCBs +/- 25% is not expected to significantly impact the Lower Hudson. The best-estimate break-even point with MNA occurs within 25 years. Additional evaluation is underway. The daily load criteria will be set in consideration of the proposed flexibility in the Productivity Standard's schedule and the constraints of the Resuspension Standard's water quality criteria.	Maintain productivity while protecting the Lower Hudson River.
Revise the station of compliance for load to be Waterford, exclusively.	N/A	Waterborne PCB concentrations decrease with distance from dredging. The focus of the analysis of load in the 2004 Resuspension Standard documents was loads that would be released to the Lower Hudson; such loads are best measured at Waterford. Thus, this change is consistent with the intent of the performance standard.	No impacts are expected.
Reduce the near- field net suspended solids (TSS) levels for Phase 2.	Net increase of 50 mg/L TSS above ambient (upstream) conditions at a location: • 300 m downstream of the dredging operation, or	Conditions during Phase 1 showed that current suspended solids criteria are too high to be useful and lower criteria are achievable and needed to monitor solids transport and releases. Proposed levels are consistent with observations of suspended solids	No impacts are expected.

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
	• 150 m downstream from any TSS control measure. Sustained TSS of 100 mg/L above ambient (upstream) conditions at near-field stations located: • to the side of dredging operations, or • 100 m downstream of dredging operations.	during Phase 1 and should not result in the need for more stringent practices than applied in Phase 1 with respect to suspended solids control.	
Use the 500 ng/L threshold at Thompson Island as a trigger to require operational changes, but not necessarily an operational shutdown, at EPA's discretion.	N/A	Phase 1 showed more than a factor of 2 reduction in water column concentrations from Thompson Island Dam to Waterford. Operational changes should be made, as needed, in response to changes in water column sample composition (*e.g.,* congener pattern, oil phase, dissolved vs. suspended contamination, etc.). Split sample precision should be considered when selecting operational changes. This proposed change will not impact water supplies because Waterford and Halfmoon have an alternate connection to Troy, and Stillwater (which draws its water from an aquifer adjacent to the river) has treatment.	Avoid unnecessary operational shutdowns and improve productivity.
Maintain the water column Control Level of 350 ng/L for discretionary use by EPA to	N/A	During Phase 1, few operational changes were made prior to exceeding the 500 ng/L threshold. Exceeding the	Provide early action to avoid operational shutdowns and maintain productivity.

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
require (as opposed to merely recommend) appropriate operational changes.		500 ng/L threshold may be avoided by proactive adjustments to the operation.	
Residuals			
Reduce the number of cases from 8 to 4 primary response categories.	The four maintained cases are: 1. The standard is met or almost met 2. Residuals are present 3. Inventory is present 4. Recalcitrant residuals or inventory is present	The intention is to simplify and streamline the standard based on Phase 1 results. Four of the cases included in the Residuals Standard were not encountered during Phase 1 and are not likely to be encountered during Phase 2.	This may have some benefit to resuspension and productivity by shortening the time for CU closure.
Remove the 20-acre averaging option and backfill testing requirement.	N/A	The conditions where the 20-acre averaging could be applied did not occur during Phase 1 and are unlikely to occur in Phase 2.	This will have some benefit to resuspension and productivity by avoiding longer times for CU closure.
Eliminate use of the 99% UCL (6 mg/kg criterion) as a basis to decide CU sampling requirements.	N/A	Rather than use 6 mg/kg criterion to trigger sampling at depth, full penetration and analysis of all 6-inch core segments in a minimum 24-inch core (unless bedrock or dense clay is encountered) will be required for all post-dredging cores due to Phase 1 experiences with missed inventory and underestimated DoC.	This will improve productivity by eliminating multiple, unnecessary re-dredging passes and sampling rounds to address missed inventory.
Permit capping without formal petition to EPA only after completion of the first pass and at least 1 additional dredging pass targeting only the top 6 inches of material. In other	No numerical criteria are changed for this revision. This applies only to Case 4 – Recalcitrant Residuals or Inventory Present	The Residuals Standard contemplated limited capping as a contingency to address residuals in the presence of difficult bottom conditions. The option for capping is not meant to compensate for any deficiency in	When underestimates of DoC have been remedied, re-dredging to capture inventory will be reduced, improving productivity and reducing resuspension. The targets

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
words, in order for capping to be permitted, the inventory must have been removed as confirmed by post-dredging coring and an additional pass targeting just 6 inches (residuals) must have been performed.		dredging design. However, during Phase 1, capping was sometimes employed primarily to isolate inventory and this should be avoided in Phase 2.	within the Productivity Standard are designed to accommodate some re-dredging.
Confirm DoC in post-dredging cores.	Two contiguous segments less than 1.0 mg/kg Total PCBs are required to confirm that DoC is known.	During Phase 1, there were situations where sediment cores were observed to reach a value of less than 1.0 mg/kg in a single 0 to 6-inch segment only to see concentrations rise again deeper in the profile.	This is an important component of defining DoC, thereby minimizing the number of dredging passes in order to maintain productivity targets and minimize resuspension.
Simplify identification of non-compliant nodes for reviewing dredging pass results.	Target average value of 1.0 mg/kg Tri+ PCB, using only the ranked, measured nodal values in a simple accumulating average.	As implemented in Phase 1, locations that appeared to be compliant with the standard on one pass caused the mean to exceed the Residuals Standard threshold after later passes, requiring re-dredging (or capping) in the previously compliant location. This problem is eliminated by this simplified process.	This will make the second dredging pass laterally more extensive, capturing inventory more quickly, leading to faster closure of CUs to maintain productivity and minimize resuspension.
Simplify identification of re-dredging or capping boundaries.	The area associated with non-compliant nodes extends to the periphery of compliant nodes or to the edge of the CU. Where a compliant node is surrounded by non-	In Phase 1, a sophisticated algorithm was a source of much discussion and often resulted in unusual dredging geometries. A more conservative approach is needed in light of poor spatial correlation and DoC	Simplified geometry will shorten the design and decision period between dredging passes leading to faster closure of CUs to maintain productivity and

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
	compliant nodes, the area associated with the compliant node is dredged to the average depth of the surrounding non-compliant nodes. Generally, 3 compliant nodes are required to define an area that does not require re-dredging.	uncertainty.	minimize resuspension.
Identify nodes with high probability of exceeding the Residuals Standard threshold early in the CU dredging process to mitigate uncertainty in DoC estimation.	Target concentration of 1.0 mg/kg Tri+PCB, permitting only a mean of 1.49 after the last pass.	As implemented in Phase 1, locations that appeared to be compliant with the standard on one pass later caused the mean to exceed the Residuals Standard threshold after later passes, requiring re-dredging (or capping) in the previously compliant location. Areas identified in this manner will meet the true threshold of 1 mg/kg, regardless of the outcome of subsequent re-dredging attempts at the non-compliant locations.	This will make the second dredging pass laterally more extensive, capturing inventory more quickly, leading to faster closure of CUs to maintain productivity and minimize resuspension.
Avoid capping in the navigation channel whenever possible. If it is necessary, however, design and implement such that the top of cap allows for a minimum of 14 feet of draft to allow for future maintenance dredging by the NYS Canal Corporation	Caps must allow 14 feet of draft in navigation channels.	Capping was not expected in the navigation channel. However, during Phase 1 the installation of a subaqueous cap was required in and around Rogers Island. The caps in the navigation channel were placed such that the navigation depth of 12 feet was met. The 12-foot depth, however,	Because sediments deposited in the established navigation channel historically dredged to a depth of 14 feet are expected to be softer and readily dredged, except possibly where debris exists, this is expected to have a

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
(NYSCC).		does not account for the need to conduct maintenance dredging of sediments that become naturally deposited on top of the cap. The tops of any caps placed in the navigation channel in Phase 2 must be at least 14 feet deep in order for NYSCC to maintain adequate channel depths.	minimal impact on productivity.
Eliminate the concepts of 'inventory pass' and 'residuals pass' from the Residuals Standard. Consider all passes simply as dredging passes.	N/A	Rarely in Phase 1 was subsequent dredging after the first pass exclusively done to remove inventory or residuals. The categorization of particular dredging passes, which has no impact on implementation of the Residuals Standard, became a distraction during project discussions.	No impacts are expected.
Productivity			
Add a provision to extend the time frame for Phase 2 at the discretion of EPA.	Every reasonable effort will be made to maintain the 5-year duration of Phase 2. EPA may allow 1 or 2 additional years if conditions require.	This change allows EPA to adjust the project schedule if necessary to accommodate conditions beyond the control of EPA and GE, such as extreme flows, force majeure, or the discovery of significant additional inventory to be removed; as well as possible resuspension impacts, which are the subject of ongoing analysis by EPA.	The project will still be required to meet a PCB load threshold based upon the amount of mass to be removed and protection of the Lower Hudson River.
Recalculate the annual required and target dredging volumes to reflect the revised Phase 2 removal volume.	Required volume: Yrs 1 to 4 - 475,300 CY/Yr Yr 5 - 475,300 CY* Avg. daily - 3,378 CY	This modification is consistent with the design intent of the standard and is based on a Phase 2 schedule of 5 years and the current estimate of	The project will still be required to meet a PCB load threshold based upon the amount of mass to be

Table ES-1. Proposed Changes to the Performance Standards (cont'd)

Proposed Change to Standard	Proposed Numerical Criteria	Rationale	Impact on Other Standards
	Avg. monthly - 86,420 CY Target volume: Yrs 1 to 4 - 528,100 CY/Yr Yr 5 - 264,100 CY* Avg. daily - 3,745 CY Avg. monthly - 96,020 CY *or remaining inventory	remaining inventory to be removed (~2.4 million CY).	removed and protection of the Lower Hudson River.
Count sediment volumes removed during residuals dredging and when dredging missed inventory toward meeting required and target volumes listed in the Standard.	N/A	GE requested, and EPA approved, a change for Phase 1 to count missed inventory, and it should be carried forward into Phase 2, as well as residuals dredging volumes. Since there is some uncertainty in the remaining inventory to be dredged for Phase 2, since overcuts may be required to address uncertainty in the existing DoC information, and since all dredging activities will contribute to resuspension losses, these dredged volumes should be counted toward the productivity targets.	No impacts are expected.

RESUSPENSION STANDARD FINDINGS

- The Resuspension Standard functioned as designed during Phase 1, and monitoring data collected were used to temporarily halt dredging operations when the 500 ng/L criterion was exceeded on three occasions.
- Dredging operations and processes can be improved and streamlined to increase productivity and reduce resuspension.
- At Thompson Island, Lock 5, and Waterford, the 7-day running average net loadings for Total PCBs and Tri+ PCBs were exceeded. The total Phase 1 PCB load control levels were also exceeded. However, EPA's goal of a maximum 1 percent loss rate to the Lower Hudson River was achieved.
- The monitoring data on PCB concentrations in the river water show no dredging impacts to water quality in the Lower Hudson River.
- River water concentrations of PCBs returned to pre-dredging levels in the Upper Hudson River once all in-river activities ended.
- Fish tissue impacts were limited to the vicinity of dredging. The current data do not indicate that dredging had an effect on PCB levels in fish more than 2 to 3 miles downstream of the Thompson Island Pool.
- EPA anticipates that any dredging-related, localized body burden increases of PCBs in fish that are observed in the short term will rapidly return to baseline levels, and continue to decline thereafter following remediation.
- Several factors contributed to the resuspension of PCBs, including: PCB mass and volume removal, vessel traffic, disturbance of exposed contaminated surface sediments, backfill processes, and efficiency of dredge bucket use.
- The data do not demonstrate that the dredging led to significant redistribution of contaminated sediments to non-dredged areas. Baseline water concentrations in the Upper Hudson have returned to normal, lending further support to this finding.
- PCBs in the vicinity of the dredging operations were dominated by dissolved and PCB-bearing oil (NAPL) phases. Suspended solids concentrations were not a good predictor for Total PCB transport downstream of the dredging operations.
- The PCB load criterion of 650 kg established at the time of the ROD should be revised upward to reflect the following observations: baseline loads to the Lower Hudson are about 3 times greater than EPA's model predicted; the surface sediments are not being buried and their concentrations are 3 times higher than predicted by the model; and the amount of PCBs to be removed is 2 to 3 times higher than estimated in the ROD. These factors all indicate that the currently expected short-term PCB releases will be more than offset by the long term improvements in PCB load and exposure resulting from the remedy.

RESIDUALS STANDARD FINDINGS

- Phase 1 removed as much or more PCB mass and volume than called for in the ROD, even though 8 CUs or areas were not addressed.
- The Total PCB mass and volume removed were roughly 1.5 times higher than the original estimates in the design for the areas dredged. More PCB mass and volume were discovered than anticipated.
- Operations and processes (depth of contamination, efficient dredging passes, sampling, analysis, and time to closure of dredged areas) can be improved and streamlined to increase productivity and reduce resuspension.
- The PCB sediment inventory in the Phase 1 CUs was reduced by 98 percent, excluding CU-1, meeting the ROD goal of 96-98 percent removal. This is largely due to the Residuals Standard's post-dredging sampling requirements, which detected contaminated sediment inventory that was not encompassed by the initial dredging cut lines.
- Efficient dredging and closure of areas in Phase 1 were hampered by an inaccurate estimate of the depth of the contaminated sediment inventory. Multiple dredging passes were required to remove the contaminated sediments. This adversely affected resuspension and productivity.
- The Residuals Standard was designed to remove most of the contaminated sediments in the first dredging pass. The impact of the poorly defined depth of contamination resulted in removing only 49 percent of the actual inventory by volume and only 58 percent of actual inventory by mass in the first dredge pass.
- Because the initial dredging pass did not remove the full contaminated sediment inventory and multiple dredging passes were required in each CU to address inventory, the application of the Residuals Standard served to detect inventory rather than to sample and manage comparatively thin layers of dredging residuals. The number of dredging passes could have been reduced had the depth of contamination been robustly re-characterized following the initial dredging pass.
- Each dredging pass successfully reduced sediment PCB concentrations.
- The inaccurate estimate of the depth of contaminated sediment was due, in part, to the presence of wood debris. Improvement needs to be made in the collection of cores, especially after dredging, including actions to re-confirm the depth of contamination. Deposits of contaminated wood debris should be removed entirely, where encountered, as a component of the dredging project management.
- The uncertainty in depth of contamination should be addressed by setting the dredging cut line to the bottom of the first six-inch core segment (rather than the top) with a Total PCB concentration less than or equal to 1 mg/kg and adding 3 inches for uncertainty in dredging precision. An overcut of 3 inches should be added to subsequent passes targeting 6 inches.

PRODUCTIVITY STANDARD FINDINGS

- The volume of contaminated sediments dredged during Phase 1 (approximately 280,000 CY) exceeded the required volume (200,000 CY) by 40 percent and also exceeded the targeted volume (265,000 CY); this volume was removed from 10 of the 18 certification units (CUs) targeted for dredging in Phases 1 (the remaining 8 CUs will be dredged in Phase 2).
- In addition, approximately 80 percent more PCBs (20,000 kg) were removed than targeted for the 10 CUs dredged during Phase 1 (11,000 kg)
- The targeted volume of sediments to be removed on a monthly basis during Phase 2 (86,000 CY) can be attained through improvements in operations.
- The maximum monthly dredging production rate achieved during Phase 1 was approximately 78,000 CY (GE estimate), only 12 percent less than the Phase 1 requirement of 89,000 CY. The production rate was largely limited by an inability to unload scows (barges) arriving at the dewatering site at the rate that they were filled by the dredges.
- More than 4,700 hours (more than a quarter of the available dredging hours) were lost while dredges sat idle waiting for scows to be unloaded. Had empty scows been available, the maximum monthly dredging rate could have exceeded 110,000 CY.
- Pre-design sampling failed to provide an accurate definition of the depth of contamination in areas dredged in Phase 1. In the 10 CUs that were completed during Phase 1, approximately 1.8 times more sediment was removed than was estimated for them in the design. Phase 2 volumes are expected to increase by about 1.5 times over GE's original design.
- Productivity was also slowed by the need to re-define dredge cut lines multiple times in most CUs and to make additional passes to remove previously unidentified contaminated sediments (inventory) below the original cut lines.
- Higher-than-anticipated rates of PCB resuspension resulted in a loss of approximately 1,000 hours (only 6%) of available dredging time during Phase 1.
- The volume of sediment remaining to be dredged in Phase 2 has been revised based on the Phase 1 observations and is now estimated at approximately 2.4 million CY. Approximately 475,000 CY per year will have to be dredged to complete this work in a 5-year time frame.
- Dredging productivity requirements for Phase 2 can be met through changes in the scow unloading operation, a loosening of tight tolerances for meeting design cut lines, and other design and operational changes.

INTRODUCTION

INTRODUCTION

Purpose

In February 2002, the United States Environmental Protection Agency (USEPA, or EPA) issued a Record of Decision (ROD) (USEPA, 2002) for the Hudson River PCBs Superfund Site (Site). The ROD called for environmental dredging targeting approximately 2.65 million cubic yards (CY) of polychlorinated biphenyl (PCB)-contaminated sediment from the Upper Hudson River (approximately 40 river miles between the former Fort Edward Dam and the Federal Dam at Troy, NY), and monitored natural attenuation of the contamination that may remain in the river after dredging.

The ROD stipulated that remedial dredging will be conducted in two phases. Phase 1 dredging was to be implemented at less than full-scale operation, and was to include an extensive monitoring program of all operations. In selecting its cleanup remedy, EPA required establishment of performance standards for resuspension, production rates, and PCB residuals, together called "Engineering Performance Standards for Dredging." EPA said that these standards would promote accountability and ensure that the cleanup meets the human health and environmental protection objectives set forth in the ROD. The peer-reviewed standards were published in final form in April 2004.

The ROD states that dredging equipment and methods of operation were to be selected based on their expected ability to meet the performance standards. The information and experience gained during the first phase of dredging are to be used to evaluate and determine compliance with the performance standards. Further, the data gathered were expected to enable EPA to determine if adjustments are needed to Phase 2 dredging operations or the performance standards. The ROD also states that EPA will continue to monitor, evaluate performance data and make necessary adjustments during the full-scale remedial dredging in Phase 2.

General Electric Company (GE) implemented the Phase 1 dredging based on the requirements of the ROD and the 2006 Consent Decree. The purpose of this report is to evaluate the Phase 1 dredging operations with respect to the Engineering Performance Standards, to set forth proposed changes to the Engineering Performance Standards, and to evaluate the experience gained from Phase 1 dredging operations relevant to the issues in the charge to the independent peer review panel that will evaluate this report, and the similar report to be prepared separately by GE. Some of the matters and issues discussed in this report and its appendices are beyond the scope of the peer review. EPA has included such material in the report to inform the public and provide background and contextual information for the Peer Review Panel.

The peer review panel has been given a set of charge questions to address in their review of the documents. In summary, the charge questions address whether the Engineering Performance

Standards can be met individually and simultaneously during Phase 2 of the dredging project, with consideration of any proposed modifications to the Standards.

Brief Summary of the Performance Standards

The Resuspension Standard was designed to monitor and control PCB concentrations in the water column of the Hudson River during dredging activities. Its primary objectives were to create a framework to maintain PCB water column concentrations below the 500 ng/L federal drinking water Maximum Contaminant Level (MCL) in order to protect public water supplies and to minimize the release of PCBs from dredged sediments and control their downstream transport. The criteria included in the Resuspension Standard were developed from the federal drinking water MCL, baseline monitoring, and an estimate of the total mass of PCBs to be removed from the Hudson River during the project.

The Residuals Standard consists of procedures for managing residual sediment contamination following the removal of the entire contaminated sediment inventory at a particular dredging area, or Certification Unit (CU). The design cut lines intended to define the bottom of the inventory to be removed were based on results derived from the pre-dredging sediment sampling and analysis plan (SSAP) developed and implemented by GE. The Residuals Standard includes the implementation of a post-dredging sampling and analysis program to quantify PCB concentrations in residual sediments and a set of required actions based on the detected concentrations. The Residuals Standard requires the collection and analysis of 40 sediment cores from each CU following the removal of sediments to the design cut line. The sediment cores are divided into 6-inch segments. The 0-6 inch segment is analyzed immediately for PCBs, and deeper segments are archived should additional data at depth be needed to design subsequent dredging passes. Based on the sediment analytical results and the number of prior dredging passes conducted, a particular CU may be closed with backfill, re-dredged, evaluated in concert with other nearby CUs, or closed with an engineered cap.

The Productivity Standard establishes a schedule for the dredging project and provides guidelines for monitoring its progress to ensure that it is completed within the time period identified in the ROD. The Productivity Standard requires compliance with minimum cumulative volumes of sediment to be removed during each dredging season.

Organization of this Report

EPA's Phase 1 Evaluation Report is organized into the following sections:

- **Introduction**. Outlines the purpose of the Phase 1 Report, briefly describes the performance standards, evaluates the overall implementation of the performance standards for Phase 1, summarizes conclusions regarding the implementation of each standard, and lists and analyzes proposed recommendations and changes with regard to individual and simultaneous implementation of the performance standards during Phase 2.

- **Chapter I – Evaluation of the Resuspension Standard Implementation**. This chapter describes the Resuspension Standard as implemented in Phase 1, the baseline monitoring program conducted to determine pre-dredging water column concentrations and loads, and evaluates the Phase 1 water column monitoring data with respect to the standard's criteria and the project activities. Observations of unanticipated PCB-contaminated oil releases and resuspension from dredging activities are considered with regard to the Phase 1 findings. Recommendations are provided for controlling suspected sources of resuspension in Phase 2 along with proposed changes to the load standard thresholds and data collection.

- **Chapter II – Evaluation of the Residuals Standard Implementation**. This chapter describes the Residuals Standard as implemented for Phase 1. Evaluations of the Phase 1 post-dredging sampling data are provided that show the connection between the larger-than-anticipated dredging volumes and the lack of a robust characterization of depth of contamination (DoC) in many of the CUs. Recommendations are provided to streamline the application of the Residuals Standard in view of the conditions encountered during Phase 1.

- **Chapter III – Evaluation of the Productivity Standard Implementation**. This chapter describes the Productivity Standard as implemented for Phase 1. A summary of the details of project implementation is provided, addressing dredging-related work elements from tree trimming and debris removal to the processing and off-site shipment of dredged sediments and reconstruction following dredging. Phase 1 dredging productivity is evaluated in terms of cubic yards removed, available work time, and delays/lost hours due to various problems and constraints. Impacts to navigation are discussed and recommendations are provided to maintain Phase 2 productivity targets.

- **Chapter IV – Proposed Changes to the Performance Standards**. This chapter discusses the proposed modifications to the performance standards for Phase 2, and the basis for each recommendation. The proposed changes are evaluated to examine how they will affect the individual and simultaneous implementation of the standards.

Overview of Phase 1 Operations and Oversight

Phase 1 Operations

Phase 1 operations involved mechanical dredging in selected certification units (CUs) of about 5 acres each in River Section 1, known as the Thompson Island (TI) Pool. Of the 18 CUs originally planned to be dredged in Phase 1, only 10 CUs were actually dredged due to the larger than expected volume of PCB contaminated sediments found in those CUs. Dredged CUs include CUs 1 through 8 at the northern end of the pool, and CUs 17 and 18 located toward the southern end of the pool near Griffin Island (parts of what was formerly known as *Hot Spot* 14, historically considered one of the most contaminated areas in the Upper Hudson River). While CU-1 through 8 were chosen for Phase 1since they were the upstream-most areas for remediation, CU-17 and 18 were chosen for Phase 1 to represent fine-grained sediments areas so as to cover a range of dredging regimes and bottom conditions expected over the course of the project.

The dredges used during Phase 1 of the project consisted of fixed arm, hydraulic excavators mounted on deck barges and equipped with hydraulically operated, enclosed environmental buckets that produce a relatively level cut. A total of 12 dredges were available for most of the season. Five dredges were equipped with 5-CY buckets, one with a 2-CY bucket, and six with 1-CY buckets. Each dredge was equipped with a Real-Time Kinematic (RTK) Differential Global Positioning System (GPS) to position the dredge bucket within tolerances of ± 2 inches vertically and ± 3 inches horizontally.

Contaminated sediment was placed in scows as it was dredged and moved by tug boat to the dewatering facility on the west side of the Champlain Canal north of Lock 7. A number of different size scows were used for the project. A total of 18 large hopper scows (~195 ft long by 35 ft wide by 12 ft deep) with double walls were available for use in areas where the depth of water was adequate to accommodate their draft. In addition, 9 “mini-hopper” scows measuring approximately 26 feet by 18.5 feet and one measuring approximately 52 feet by 18.5 feet were available for use in shallow areas of the river; all had 2-foot high walls. Typically, about 20 CY of sediment could be placed in each smaller scow and 40 CY in the larger scow before the material was transferred to a large hopper scow moored in deeper water. One of the 5-CY dredges was dedicated to transferring the material to the larger scows for much of Phase 1 dredging. Although the number of scows should have been adequate to keep up with dredge production, unanticipated limitations at the unloading and dewatering facility resulted in a shortage that affected dredging production.

Seventeen 3-foot draft tugboats were used to move scows and other barges. Typically, two tugs were required to move a large hopper scow from the dredging operations to the unloading wharf, although three tugs were occasionally used when river flows and current velocities were high. Four other utility tugs with outboard motors were also available; three were used to move mini-hopper scows, and one was used in conjunction with a maintenance barge. The total number of vessels on the river at any one time approached 90 when all survey boats, dredges, tugs, water taxis and ancillary craft were operating.

Backfill and capping materials were stockpiled on the west shore of the river opposite Rogers Island and loaded onto barges using a conveyor system. The backfill and capping materials were placed using the same excavators used for dredging, but mounted with different buckets. Eight deck barges of varying sizes up to approximately 35 feet wide by 196 feet long were used to transport backfill and capping materials from the stockpile area to the point of use in the River; materials were transferred to mini-hopper scows for placement in shallow water areas. The bucket positioning systems on the excavators were used to control the location and rate of swing of the excavator arm and the opening of the bucket jaws above the water surface as the backfill or capping material was installed.

The dewatering facility was designed to handle an average of 3,500 CY and a peak of 5,100 CY of dredged sediments per day. Loaded scows arriving at the wharf were moored adjacent to a pump-out station where free water was removed. (Because the pumps require a head of approximately 1 foot of water over their inlets, they were not capable of removing all of the free water from a scow.) The scow was then repositioned adjacent to an excavator with a 5-CY bucket to remove the sediment. In order to maintain unloading production as the depth of sediment remaining in the scow fell below the efficient cutting depth of the bucket, a smaller remote-controlled excavator was lowered into the scow to push the sediment into a pile. For these reasons, scow unloading exerted the greatest limitation on the availability of scows. Because dredging typically did not occur on Sundays but scow unloading continued, scows tended to be more readily available at the beginning of the week, while not being available in sufficient numbers later in the week. This resulted in declining productivity over the course of the week.

Materials unloaded from the scows were separated into coarse and fine fractions. If the scow contained mainly coarse material, it frequently could be transported directly to the coarse material staging stockpile. Other sediments were separated by size using a grizzly screen (for exclusion of debris), trommel screen, and hydrocyclone. The underflow from the hydrocyclones was dewatered on fine mesh shaker screens and stockpiled for transport to the coarse material staging area. The over flow was pumped to a sediment slurry thickening tank where polymers were added prior to being dewatered in plate and frame filter presses. If all 12 presses were operating with a cycle time of 3 hours, they could produce up to 2130 CY of filter cake per day. Filter cake dropped into roll-off containers and was transferred by tilt-bed truck to the fine material staging area. Dewatered sediment was loaded into gondolas fitted with plastic sacks and shipped by rail to the WCS landfill located west of Andrews, Texas, near the Texas-New Mexico border. Sufficient gondolas were available to provide up to 5 unit trains (81 cars per train) at any time.

A comprehensive summary of the major in-river activities associated with dredging and closure of each Phase 1 CU on a day-by-day basis is depicted in Figure Intro-1 provided in a pocket at the end of the section. This figure covers the entire Phase 1 period from navigational dredging adjacent to the unloading wharf in early May 2009 through completion of all backfill and capping in the third week of November, as well as final EPA approval of closure forms in late November and very early December. For each CU, the figure shows time occupied by debris removal, dredging, surveying, core collection and analysis, backfill and capping, submittals and

EPA approvals. Typically dredging was not performed on Sundays, which were used for maintenance activities and catching up on scow unloading; Sundays are denoted by dashed vertical lines. The figure also shows a summary of miscellaneous activities in CUs 9-16, which were originally planned to be dredged in Phase 1 but were ultimately excluded due to schedule constraints. Note that minimal dredging was initiated in CU-9 at the beginning of Phase 1 as part of the kickoff demonstration, but was not resumed.

Field Oversight

EPA's oversight team observed the Phase 1 dredging program from debris removal through dredging, sediment transport and unloading, sediment processing and loading into gondolas for rail transport to the disposal facility, as well as backfill, capping and shoreline stabilization operations. Their observation experiences have led to insights regarding a number of areas of potential improvement in consideration of "lessons learned" in Phase 1. EPA and GE have begun discussing these observations to identify operations and approaches that could benefit from further changes. These changes would support continued compliance with Engineering Performance Standards and the Quality of Life Performance Standards. Some key items EPA and GE plan to discuss include: efficiency of the unloading and separation operations at the sediment processing facility, control of PCB NAPL, management of scows and dredges, procedures when clay or bedrock are encountered, decanting of dredge bucket water, quality of dredge cuts, handling of debris, shoreline stabilization, Certification Unit preparation and review process, data sharing, cultural resources, vessel movement and management and control of PCB air emissions. It is anticipated that these discussions will guide future design revisions. The oversight team's observations have been collected in a Phase 1 Oversight Report, which is included as Appendix I-H.

Many of the issues highlighted by EPA are also discussed in an oversight report prepared by the New York State Department of Environmental Conservation (NYSDEC), which is attached in Appendix Intro-1. EPA does not necessarily endorse all of the NYSDEC findings but does believe a number of the items pointed out in the report are relevant to the continued success of the project. Also included in the Appendix is a slide presentation by the NYSDEC summarizing their observations and findings.

Consequences of Underestimated Depth of Contamination in Phase 1

Ten of the 18 CUs originally planned to be addressed in Phase 1 were actually dredged in the 2009 season. However, a greater volume of sediment was dredged in Phase 1 than planned. This occurred because the design cut lines in every CU underestimated the true depth of contamination required to be removed in accordance with the ROD. Overall, if design volumes are adjusted for setbacks necessary adjacent to structures and for managing sediments at the shoreline, the amount dredged in the 10 CUs was nearly double the originally planned volume.

Further, some contaminated sediment inventory that otherwise should have been removed was capped in place due to the impending closing of the Champlain Canal locks at the end of the season. This underestimation of the depth of contamination (DoC) had a profound effect on the conduct and outcome of Phase 1. The causes and impacts on achieving compliance with all three performance standards are discussed in detail in subsequent sections of this report.

The consequences of accurately estimating DoC and underestimating DoC are illustrated in Figures Intro-2 through Intro-4. Figure Intro-2 represents the scenario envisioned as the ideal in development of the Residuals Standard where DoC is accurately known. In this ideal scenario, the inventory is removed on the first pass (assuming an overcut of 6 inches to address uncertainty) and the second dredging pass is needed only for disturbed residuals. The other two figures show actual examples from two CUs: CU-3 and CU-18. Figure Intro-3 shows a location in CU-18 where DoC was fairly accurately estimated and the design cut lines worked well. Dredging was completed in two passes,[1] of which the latter encompassed just 6 inches of sediment, presumed to be residuals. In the last case (a location in CU-3, as shown in Figure Intro-4), underestimated DoC caused multiple re-dredging passes as additional inventory was discovered through implementation of post-dredging sampling required by the Residuals Standard.

<u>Ideal Dredging Scenario</u> (see Figure Intro-2)

- In this simplified, ideal dredging scenario, high-confidence (Level 1A) SSAP cores have accurately estimated the DoC, and the design DoC has been set at the lower boundary of the existing contaminated sediment inventory.
- In the first dredging pass, sediment is removed beyond the design DoC, and the dredge cut extends into the underlying clean material. The bulk of the targeted inventory is removed in the first dredging pass.
- Immediately after the first dredging pass, it is essential to conduct verification sampling and to analyze a full 24-inch post dredging core to effectively characterize the amount of inventory that may remain.
- The second dredging pass addresses residual sediments in accordance with the Residuals Standard. The residual sediments are removed, leaving behind a surface with sediment concentrations less than 1 ppm Total PCB.
- In this idealized case, no additional dredging passes are necessary.

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[1] An important distinction in the Hudson River project is that the term "dredging pass" refers to dredging a CU to a planned depth and not to a single set of bucket cuts as it might in other projects.

CU-18 (see Figure Intro-3)

- There are 7 high-confidence (Level 1A) SSAP cores in this location, in the southwest portion of CU-18. All but a very small number of SSAP cores in CU-18 were high-confidence (Level 1A), including all cores in the immediate vicinity of this example location.
- Based on the DoC observed in the SSAP cores, the design thickness of cut was 1.5 ft. (18 in.)
- Due to deposition observed in the time period between design and actual dredging, the actual cut thickness was 1.6 ft (19.2 in.).
- Post-dredging cores in this vicinity identified contamination in the top segment 0.5 ft (6 inches) and the concentration in the remainder of the core length was less than 1 mg/kg.
- Two dredging passes were performed in this location.
- The average cut thickness during the first dredging pass was 1.76 ft. The average cut thickness for the second dredging pass was an additional 0.6 ft
- In total, an average inventory thickness of 2.45 ft was removed in this area over a series of two dredging passes, compared with a planned 1.6 ft based on the 2009 bathymetry and SSAP cores.
- This was one of a relatively small number of areas where the first pass (based on cut lines developed using a preponderance of high-confidence cores) removed the bulk of the inventory, and the second pass was a true residuals pass as envisioned by the Residuals Standard. However, a preponderance of high-confidence cores did not necessarily result in the first pass removing the bulk of the inventory in many of the Phase 1 CUs.

CU-3 (see Figure Intro-4)

- There is only 1 high-confidence (Level 1A) SSAP core in this location, in the northeast portion of CU-3. This area is surrounded by Level 2 SSAP cores.
- The DoC was estimated to be 2.5 ft. (30 in.) in the SSAP core.
- Due to deposition observed in the time period between design and actual dredging, the actual cut thickness necessary to reach the design cut line was 2.75 ft (33 in.).
- Post-dredging cores in this vicinity, collected after the initial dredging pass, identified an additional 1.5 ft (18 in.) of inventory in this area, making the redesigned DoC at 4.25 ft. (52 in.).
- Subsequent post-dredging cores identified additional 1.5 ft (18 in.) of inventory and 0.5 ft (6 in.) of material with Total PCB concentration less than 1 ppm.

- Three dredging passes (the initial and two additional dredging passes) were performed in this location.
- A post-dredging core collected after the third dredging pass reported residual contamination in the surface segment (0.5 ft) and the absence of PCB sediment inventory in the remainder of the 2 ft core (6 to 24 inches).
- The residual contamination was capped as a part of CU completion.
- In total, an average inventory thickness of 5.75 ft was removed in this area over a series of three dredging passes, compared with a planned 2.75 ft based on the 2009 bathymetry and SSAP cores.

Evaluation of Phase 1 Performance Standards Implementation

The following table provides a summary evaluation of the implementation of the performance standards during Phase 1.

Criterion or Goal	Phase 1 Evaluation
Resuspension Standard	
Near-field TSS (100 m) Evaluation Level 700 mg/L	Average TSS well below Evaluation Level for Phase 1.
Near-field TSS (300 m) Evaluation Level 100 mg/L	Average TSS well below Evaluation Level for Phase 1; four exceedances were observed but not supported by continuous turbidity measurements.
Max. allowable Total PCBs in water column 500 ng/L	Exceeded in three instances; total time that dredging activities were halted was less than four days.
Far-field net suspended solids concentration Evaluation Level 12 mg/L	Not exceeded.
Far-field Total and Tri+ PCB load Control Levels of 1,080 g/day and 361 g/day based on the anticipated PCB mass removal.	Exceeded at Thompson Island for the majority of the dredging period. At Waterford, the loads were significantly lower and exceeded the control level about 20 percent of the time. However, the load criteria were not revised during Phase 1 to address the larger-than-planned PCB mass removed (the removed mass was roughly 1.5 times the planned removal). Overall target of no more than 1 percent export achieved.

Criterion or Goal	Phase 1 Evaluation
Residuals Standard	
Affirmation of removal of all PCB-contaminated sediment inventory in target dredging areas	Substantial removal of inventory was confirmed in all CUs. Where inventory was left in place, the requirements of the standard were used to direct the construction of engineered caps to isolate the remaining inventory.
Arithmetic average Tri+ PCBs concentration in the residual sediments ≤ 1 mg/kg	As a measure of comparison of Phase 1 post-dredging core results to Phase 1 thresholds, every CU dredged in Phase 1 required re-dredging after the initial pass to remove contaminated sediment inventory not captured by the initial design cut-lines. On average, the percentage of nodes that required re-dredging out of all the nodes sampled are approximately 70, 30, 15, and 20 percent following the initial, second, third and fourth dredging passes, respectively.
Construction of engineered cap allowed if four dredging passes fail to produce compliant results	The majority of the dredging passes conducted during Phase 1 were focused on inventory removal. Successive dredging passes were not usually needed to remove residual sediments during Phase 1; therefore, this criterion was rarely applied as envisioned by the standard.
Productivity Standard	
Target Phase 1 dredging volume = 265,000 CY	Phase 1 volume removed ≈ 273,600 CY
Target Phase 1 monthly volume ≈ 89,000 CY (average monthly volume then anticipated for Phase 2)	Max. monthly Phase 1 volume removed ≈ 78,000 CY; however, it is very likely that had shortages of empty scows not been encountered, the monthly target would have been achieved.
Shoreline stabilization, backfilling, and processing and shipment of removed sediment accomplished prior to the end of the calendar year.	Due to difficulties at disposal site, roughly 2/3 of the processed sediment was not shipped off-site by end of calendar year 2009. Provisions should be made for a back-up disposal site for Phase 2.

Considering the information gathered during Phase 1, it can be concluded that:

- Water column suspended solids concentrations in the near-field and far-field remained below the Resuspension Standard criteria.
- Water column Total and Tri+ PCB load criteria were exceeded; however, the load criteria require adjustment to address the larger than expected mass of PCBs removed for Phase 1 and anticipated to be removed for Phase 2. Factors that may have contributed to exceedance of the load standards are identified in this document, along with potential control measures.
- Post-dredging sampling indicated that in many CUs, the DoC and design dredging cut line were not effectively set in the design phase. This situation hampered effective testing of the Residuals Standard, since post-dredging samples were often identifying previously uncharacterized inventory rather than an actual dredging residual lying above an uncontaminated sediment layer.
- The construction of engineered caps was implemented where necessary to control elevated post-dredging sediment PCB concentrations and to close CUs after a maximum required number of dredging passes had been implemented.
- The removal of contaminated sediment exceeded the minimum (200,000 CY) and target (265,000 CY) dredging volumes for Phase 1.
- Problems at the unloading wharf limited scow availability, which was the single largest factor in lost available dredging time affecting productivity.
- While the monthly Phase 1 dredging productivity did not reach the level of required monthly Phase 2 production, the required monthly production could have been achieved had an adequate number of empty scows been made available.

The Phase 1 findings for each performance standard are discussed in further detail below.

<u>Summary of Resuspension Standard Implementation</u>

The Resuspension Standard functioned as designed during Phase 1, and monitoring data collected were used to temporarily halt dredging operations when the 500 ng/L criterion was exceeded on three occasions. According to GE's estimates, these temporary operational halts consumed less than 6 percent of the available dredging hours and so EPA concludes they did not have a major impact on the ability to meet the Productivity Standard. Since dredging activities ended, water column concentrations have returned to baseline levels at all far-field stations. The field observations and sample analytical data gathered during Phase 1 have led to an enhanced understanding of the impact of dredging operations on the Hudson River water quality, as summarized below.

Low Suspended Solids Concentration Observed During Dredging

Suspended solids concentration was not a good predictor for Total PCB transport downstream of the dredging operations. Special studies show that PCBs in the vicinity of the dredge operations were dominated by dissolved and NAPL phases. There was no significant downstream transport of solids beyond the immediate vicinity of the dredging operation, based on total suspended solids (TSS) measurements. Average TSS concentrations at near-field monitoring stations were well below the evaluation criteria of 700 mg/L at 100 m and 100 mg/L at 300 m downstream of the dredging operations.

Multiple Factors Controlled Far-field PCB Transport During Dredging

The impact of dredging cannot be predicted by mass removed and river flow/velocity alone. Statistical analysis indicate that several processes may be contributing to the PCB transport to the far-field at Thompson Island The most likely factors contributing PCBs to the water column are not unexpected—mass and volume removal, vessel traffic, disturbance of exposed contaminated surface sediments, processes associated with backfilling, and the extent to which dredge buckets may be overly full or dredging is hurried. A statistical model accounting for these variables can explain about 60 percent of the variability in water column PCB concentrations at Thompson Island during dredging. The following field observations provide further support for the premise that a multitude of factors contributed to water quality impacts:

- Release of PCB-bearing oils from the sediments during dredging. These oils were observed as sheens on the water during oversight and were also sampled and analyzed during Phase 1; however, the oils were not isolated for analysis such that a specific congener pattern could be identified. The presence of free product oil also likely hampered the collection of precise field replicates during Phase 1. The presence of oil was likely responsible for the factor of 3 or greater differences in sample replicates when concentrations approached the 500 ng/L threshold.

- Boat traffic associated with the dredging as well as other activities. Observable spikes in water column PCB concentrations in the far-field were associated with a barge that was accidentally grounded, a boat accident, and other high vessel traffic events.

- Decanting of water from dredge buckets directly into the river. Water contained with the sediment was extensively allowed to drain back to the river, potentially releasing interstitial dissolved PCBs as well as interstitial PCB-bearing oils.

- Spillage from partially-closed dredge buckets (where debris interfered with bucket closure). Both suspended solids and interstitial fluids could be released in this manner.

- Debris removal to address smaller obstructions. Debris removal took place at the beginning of the operation to remove large objects identified on the river bottom. However, subsequent debris removal attempts did not remove substantive amounts of debris but did serve to disturb and resuspend sediment.

- Non productive clean-up passes (fine grading of the sediment surface to meet close dredging tolerances), causing resuspension with little net sediment removal

Fish Tissue Impact Limited to the Vicinity of Dredging

Some increases in fish tissue PCB levels were seen in 2009 within the Upper Hudson River when compared to baseline data. The increases in fish tissue PCB levels were predominantly identified in the Thompson Island Pool (i.e., the section of the river where the Phase 1 dredging occurred), with limited evidence of responses downstream. There were no statistically significant increases in fish tissue PCBs at the Albany/Troy lower river monitoring station below the Federal Dam at Troy. Overall, the monitoring data indicated that resuspension of PCBs from sediments during dredging affected fish locally, with greatest impact in the immediate vicinity of the dredging activity, but the current data do not support the notion that dredging had an effect on PCB levels in fish more than 2-3 miles downstream of the Thompson Island Pool.

Net PCB 7-day Running Average Load Criteria Exceeded

For the majority of the project, the 7-day running average net loadings for Total PCBs (TPCB) and Tri+ PCBs at Thompson Island exceeded the Control Levels of 1,080 g/d and 361 g/day, respectively. After October 27, 2009, the daily average TPCB load at Thompson Island decreased, but estimates were still above the evaluation criteria of 540 g/d. This period coincides with backfill and cap placement and increased vessel movement.

At Waterford, the 7-day average load was less than the Evaluation Level about 50 percent of the time and exceeded the Control Level 20 percent of the time.

Seasonal PCB Load Control Levels Exceeded

The Resuspension Standard seasonal PCB load control levels for both TPCB (117 kg) and Tri+ PCB (39 kg) were exceeded at all of the downstream monitoring stations. Between May 15 and November 30, 2009, the cumulative load at Thompson Island of 437 kg was about 1.5 times higher than the load at Lock 5 (269 kg/yr) and about 3 times higher than the export TPCB to the Lower Hudson at Waterford (151 kg/yr). While elevated, the 437 kg estimated load for Thompson Island is small relative to the mass of PCB removed (20,000 kg). Tri+ PCB cumulative loads estimated for Lock 5 (123 kg/yr) and Waterford (61 kg/yr), exceeded the Control Level of 39 kg.

However, the cumulative loads of TPCB at Waterford, which is the station of importance with respect to downstream impact, did not exceed 1 percent of the mass removed during Phase 1 (*i.e.*, 200 kg for TPCB).

Low PCB Export Rate to Lower River

The PCB mass loss varied between 1 to 2 percent on a weekly basis at Thompson Island. The mass of PCB lost to the Lower Hudson River during most of the dredging period, as estimated at Waterford, was less than 1 percent. Therefore, EPA's goal of a less than 1 percent loss rate to the Lower Hudson River was achieved.

No Impact of Sediment Redistribution During Dredging

Data do not support the notion that settling of PCB contaminated sediment was a significant contributor to resuspension and recontamination of non-dredged areas. Because of the baseline dynamics of sediment movement in the river and the high degree of variability in co-located sediment concentrations, investigations during dredging indicated that sediment redistribution is unlikely to affect broad areas of the river bottom. Post-dredging water column PCB concentrations have returned to baseline levels providing further support to the fact that redistribution of contaminated sediments did not impact the river.

No Dredging Impact in the Lower Hudson River

Water column concentrations in the Lower Hudson River did not increase in response to loads from the Upper Hudson. In particular, there were no discernable increases in Total PCB or Tri+ PCBs at the Lower Hudson monitoring locations near Poughkeepsie, Port Ewen or Rhinebeck. Tri+ PCB concentrations were also unchanged at the Albany monitoring station, roughly 15 miles downstream of Waterford.

Evidence for Revising PCB Load Criteria

The PCB load component of the resuspension standard was not intended to accelerate natural attenuation of PCB problems in the lower Hudson River, but rather to ensure that the remediation of the Upper Hudson River did not worsen conditions in the Lower Hudson River over the long term. During Phase 1 dredging the loads in the Upper Hudson River were higher than expected. The effect of this was seen in higher water column samples at Thompson Island. However, in spite of these increased loads the fish tissue concentrations 2-3 miles downstream of Thompson Island were largely unaffected. Also, prior modeling analysis indicates that the effects of PCB releases due to dredging will be limited to short term impacts.

The observed baseline loads to the Lower Hudson prior to dredging were substantially greater than the model forecast of Monitored Natural Attenuation (MNA) and show very little decline. The loads to the Lower Hudson River under MNA will be substantially greater than those forecast by the model by approximately 6,000 kg over 25 years. Also the surface sediment concentrations in the Upper Hudson River remain elevated despite the passage of time and continue to provide a greater reservoir of contaminated sediments for transport to the Lower

Hudson than was envisioned when the remedy was selected. These observations provide further impetus for the remedy and revising the PCB load standard to account for the PCB mass removed and the resuspension observed in Phase 1.

Considerations for Setting a Revised Load Standard

The analysis described in Section I-3.3.9 and Appendix I-G describe a scenario wherein roughly 1 percent of the current inventory of PCBs in contaminated sediments slated for remediation is lost to the Lower Hudson River. The cumulative loads under this scenario are contrasted with those delivered under MNA. The result of this comparison indicates that a dredging-related load of this magnitude will be offset by the ensuing reduction in MNA loads with no long term impacts to the Lower Hudson. This load analysis yields a much higher load criterion to the Lower Hudson than in the original Resuspension Standard and reflects the significantly greater MNA loads and Upper Hudson PCB inventory than were estimated when the standards were first developed.

While EPA proposes to set the acceptable dredging-related loss to the Lower Hudson at roughly 2,000 kg at Waterford for the duration of the project, the proration of this load over time and to the upper river monitoring locations is still under development. EPA expects to complete this analysis in April 2010 and will at that time provide its conclusions in the form of an addendum to this report. The proration will consider a number of concerns, based in large part on the observations of Phase 1. These include:

- The observed 3-fold decline in dredging-related PCB load from Thompson Island to Waterford. This decline provides a basis to allow upstream stations to have greater PCB loads relative to Waterford.
- The distribution of the PCB inventory for remediation in the Upper Hudson. More than 80 percent of the inventory is located upstream of the Schuylerville station.
- The goal of minimizing exceedances of the 500 ng/L water column standard in the Upper Hudson.
- Reduction to the extent possible of dredging-related loads based on future improvements to the dredging operations. As described in Appendix I-G, EPA is currently developing a model relating various dredging parameters to far-field water column concentrations. The recommendations from the model analysis as well as other recommendations in this report should serve to measurably reduce the rate of PCB loss.

Revisions for Phase 2

The seasonal Total and Tri+ PCB loads and the corresponding Evaluation and Control Level loads need to be adjusted upward for Phase 2 in accordance with new estimates of the amount of inventory to be removed.

The Resuspension Standard allowed refinements to the load-based criteria (USEPA, 2004; Vol.1, Section 4.0). Specifically, these criteria in the Resuspension Standard were to be reviewed and refined if the estimate of PCB mass to be removed is significantly different from previous estimates. In fact, , the extensive sediment sampling database developed during the design and during the Phase 1 dredging program clearly documents that the mass estimate to be removed is significantly different than anticipated at the time the standard was developed. EPA is not proposing to change the acceptable rate of loss (1 percent) or the acceptable water column concentrations, but as allowed by the Standard, EPA is applying the acceptable rate of loss to the revised estimate of mass to be removed in revising the load-based criteria.

Additional controls should be implemented during Phase 2 to mitigate sources of PCBs to the water column based on lessons learned during Phase 1:

- The effectiveness of various absorbents to capture oil sheens should be investigated and the selected control should be deployed around each dredge. This investigation should consider absorbent curtains that can be anchored to the bottom to provide containment.
- The practice of draining free water from dredge buckets into the Hudson River should be curtailed to reduce dissolved and NAPL phase releases to the water column.
- Dredging related vessel and tug movement should be minimized during dredging, especially in shallow areas where there is high potential to disturb sediment.
- Debris removal should be limited to one pass for large objects. During Phase 1 subsequent debris passes yielded little debris but disturbed the sediment and should be avoided.

<u>Summary of Residuals Standard Implementation</u>

The use of Phase 1 data to evaluate the Residuals Standard's effectiveness is challenging because the majority of the dredging passes conducted in the CUs were removing inventory that was not adequately characterized prior to design and not a true, post-dredging residual. The Phase 1 design cut lines were set too shallow in general; many times even post-dredging cores did not fully penetrate the depth of the contaminant inventory. In CU-1, post dredging cores did not penetrate the depth of the contaminant inventory until the final dredging cut was made, and then only after 3-foot deep test pits were dug. Therefore, the data from these cores were not strictly pertinent to the criteria in the Residuals Standard, which were developed to characterize and manage an anticipated dredging residual approximately 0-6 inches in thickness overlying uncontaminated sediments with Tri+ PCB concentrations less than 1 ppm. It is concluded from the Phase 1 data that the Residuals Standard can be appropriately implemented and readily achieved during Phase 2 if the DoC is better characterized and appropriate overcut intervals are added to address uncertainties in the design cut lines.

During Phase 1, GE dredged 10 CUs and sampling was conducted at each CU following each dredging pass. In each of these CUs, dredging to the Phase 1 design cut line was found to be inadequate to capture the contaminated sediment inventory including wood debris. The DoC was not fully characterized during design and therefore each CU required multiple re-dredging passes in an attempt to meet the PCB concentration criteria in the Residuals Standard. The supporting information for this conclusion is summarized below:

- The final dredging depth in each CU exceeded the design cut line by 1.5 feet on average and up to 13 feet, for example, in CU-1. The maximum value in other CUs was 7 feet.
- The calculated sediment removal volume exceeded the design removal volume by about 80 percent. Excluding the smallest and largest volume increases in particular CUs, the average increase in removal volume was 1.6 times greater than the design removal volume.
- Allowing for corrections for setbacks around obstructions and corrections in bathymetry (there were setbacks/obstructions that were not accounted for in the design and bathymetric changes during the time interval between remedy design and implementation), the final removal volume for all CUs, excluding CU-1, was about 1.9 times the adjusted design volume.
- The actual mass of Total PCBs removed exceeded the design estimate by a factor similar to the volume increase (20,000 kg as compared to the design mass of 13,000 kg), a factor of roughly 1.5.
- Allowing for corrections for setbacks around obstructions and corrections in bathymetry, the actual mass removed was 1.8 times greater than the adjusted design mass of 11,400 kg.
- The impact of the poorly defined DoC can be directly observed in the observation that the first dredging pass removed only 49% of the actual inventory by volume and only 58% of actual inventory by mass.

The design cut lines were not placed accurately because the SSAP cores did not provide a dataset that allowed robust characterization of DoC in all CUs. The CUs associated with significant numbers of incomplete SSAP cores [cores that did not terminate with segment(s) below 1 ppm Total PCBs] required multiple dredging passes to remove inventory. The SSAP core information should be revisited in light of the Phase 1 results to better estimate DoC for Phase 2 (including CUs planned but not completed in Phase 1).

For many post-dredging cores, only the top 6-inch segments were analyzed, consistent with the Phase 1 Residuals Standard but missing an opportunity to re-characterize the DoC where multiple dredging passes had already indicated that the DoC was not well-known. In cases where residual cores indicate non-compliant levels of PCB contamination, it is essential that those cores also be used to re-characterize DoC, in addition to characterizing the surface concentration after the initial dredging pass to meet the design cut line.

For Phase 2 post-dredging cores, a minimum 2-foot sediment column (or to the depth of uncontaminated material as defined below, if shallower) should be analyzed as individual 6-inch segments to verify that detected PCBs are associated only with a true residuals layer and not underlying inventory. In this document, the phrase "uncontaminated" will be used to describe a sediment stratum that pre-dates and underlies the PCB-contaminated sediment. In some cases, the uncontaminated stratum may have distinct geologic properties from the contaminated sediment, such as bedrock or clay. To date the only sediment type that is known to represent uncontaminated material <u>and</u> is visually distinct is glacial Lake Albany clay. Thus this is the only material that can serve to reduce the sampling requirements for a core for the start of Phase 2. Other materials, if identified and tested, may be added to the list after sufficient Phase 2 experience. In all cases, the DoC must be well-defined by a minimum of two contiguous 6-inch core segments below 1.0 ppm Total PCB at all post-dredging sampling nodes prior to initiation of the next dredging pass. Also, the experiences gained from Phase 1 and the previous design sampling investigations show that vibracore collection is not consistently a reliable method to obtain cores for DoC determination due to refusal caused by the presence of woody debris in the subsurface.

Where debris from timber processing operations is encountered, dredging should continue without further surveying and sampling until the debris has been removed and the underlying sediments are reached. This debris-bearing material was found during Phase 1 to be extensively PCB-contaminated and should be entirely removed where encountered during Phase 2. In addition, to address uncertainties in the DoC, at locations where DoC is defined by complete cores, the design cut line should be adjusted to include, at a minimum, 3 inches below the bottom of the core segment that is below 1 mg/kg for inventory removal and residuals removal. At locations where DoC is defined by incomplete cores, the design cutline should be adjusted to include at least 18 inches below the interpolated DoC.

To reflect the lessons learned during Phase 1, the Residuals Standard should be simplified for Phase 2 to reduce the number of options to the 4 conditions generally encountered during interpretation of and response to the Phase 1 post-dredging sediment data.

Finally, many of the estimates of *in situ* PCB mass made by EPA for individual CUs and dredging passes to assess the application of the Residual Standard were also performed independently by GE. For some parameters, such as volume removed, EPA and GE results agree well but for many others, particularly PCB mass, the results do not agree well and reflect significant differences in the numerical techniques used to estimate *in situ* PCB concentrations and sediment densities.

Summary of Detailed Conclusions

This section summarizes the major observations and conclusions from application of the Residuals Standard in Phase 1. Prior to beginning this summary discussion, it is helpful to review the original goals and objectives of the Residuals Standard.

As extensively described in the original documents (USEPA, 2004), the Residuals Standard was "*designed to detect and manage contaminated sediments that may remain after initial dredging in the Upper Hudson River…,*" anticipating "*…a residual of approximately 1 mg/kg Tri+ PCBs prior to backfilling.*" As also described in the original document (USEPA, 2004), the objectives of the Residuals Standard were:

- *Affirmation of the removal of <u>all</u> PCB-contaminated sediment <u>inventory</u> in target dredging areas* (emphasis added).
- *An arithmetic average Tri+ PCBs concentration in the residual sediments of < 1 mg/kg.*

These objectives were intended to satisfy the intentions of the ROD, specifically, the expectation of "*removal of all PCB-contaminated sediments in areas targeted for remediation.*"

Various forms of residual sediments were identified in the Residuals Standard (USEPA, 2004), including:

- *Contaminated sediments that were disturbed but escaped capture by the dredge.*
- *Resuspended sediments that were redeposited (settled).*
- *Contaminated sediments remaining below the design dredging cut elevations (e.g., due to uncertainties associated with interpolation between pre-design sampling nodes or insufficient core recovery).*

A review of the objectives of the Residuals Standard in light of observations collected during the Phase 1 program indicates the following successes were achieved:

- The PCB sediment inventory in the Phase 1 CUs was reduced by 98 percent, excluding CU-1, meeting the goal of the ROD for 96-98 percent PCB mass removal. This accomplishment is largely due to the post-dredging sampling requirements in the Residuals Standard.
- The Phase 1 sediment removal volume was approximately twice the adjusted volume in the Phase 1 design (after accounting for setbacks and bathymetric changes). The presence of

substantial thicknesses of inventory found in some areas during Phase 1 after the initial dredging pass far exceeded the amounts of 'missed inventory' anticipated during development of the Residuals Standard. While a comparatively thin layer of un-dredged material can be considered residual sediment, more than 6 inches and up to 13 feet can be defined only as missed contaminated sediment inventory.

- Surface sediment PCB concentrations were greatly reduced prior to backfilling or capping of the CUs.

- Phase 1 removed more PCB mass and volume than called for in the ROD, even though 8 CU's were not addressed. This was the result of the substantial increase in the actual CU inventories as well as the selection of the CUs with the greater PCB inventories from the original planned 18. Tri+ PCB concentrations in more than 2/3 of all post-dredging coring locations (and by inference 2/3 of CU surface area) were reduced to a local average of 1 mg/kg.

- Cap placement largely addressed residual sediment contamination (less than 6 inches thick), and not inventory (greater than 6 inches of contaminated sediment). Excluding CU-1, only 16 percent of the capped nodes (representing about 2.3 acres) had contamination extending deeper than 6 inches.

- Despite the underestimated DoC and inaccurate dredging cut lines, three dredging passes were adequate to get most CUs close to compliance.

- After three dredging passes, the average number of noncompliant nodes was 14 percent of the total nodes for each CU (about 7 nodes per CU), excluding CU-1.

The extensive data set collected during Phase 1 provided information on many aspects of post-dredging sediment contamination and the accuracy of the original dredging design cut lines. The major observations and conclusions that stem from these data are outlined below. These observations form the basis for the proposed revisions to the Residuals Standard.

- The original design DoC surface was an underestimate of the actual DoC surface on a CU-wide basis. The impact of the poorly defined DoC resulted in removing only 49% of the actual inventory by volume and only 58% of actual inventory by mass in the 1st dredge pass.

- Generally, the final removal volume per CU was 1.6 times the original design volume.

- The final removal volume per CU was generally 1.9 times the adjusted volume after the design was corrected for setbacks around obstructions and changes in bathymetry, meaning most CU removals went to a mean depth nearly two times the original mean DoC, although not all locations were doubled in depth.

- The final dredging depth was more than 6 inches beyond the original design surface (*i.e.,* more than a 6-inch overcut) for nearly 70 percent of the original Sediment Sampling and Analysis Program locations. Of the remaining 30 percent, only 16 percent (about half of the 30 percent) were within ± 3 inches of the original design surface.

- The final dredging depth was greater than 12 inches beyond the original design surface for 55 percent of the SSAP locations.

- Relative to the actual DoC reported for each core (as opposed to the locally interpolated design surface), the final depth of removal was more than 6 inches deeper than the core-based DoC (*i.e.,* more than a 6-inch cut beyond the core's DoC) for about 55 percent of the original SSAP locations. Similarly, the final depth of removal was greater than 12 inches deeper than the core-based DoC for about 45 percent of the SSAP locations. Of the 45 percent of locations that had less than 6 inches of additional dredging, 15 percent (about one third) were within ± 3 inches of the original core DoC.

- The confidence level of the SSAP cores (referred to as "core quality") was not a good predictor for the amount of additional dredging needed. Complete core locations (cores with a directly measurable DoC and labeled "1A"cores) required more than 6 inches of cut beyond the design surface 65 percent of the time. Incomplete (or extrapolated cores) with only an estimated DoC had more than 6 inches of cut beyond the design surface about 75 percent of the time.

- Total PCB mass removed (20,000 kg) is roughly 1.5 times the original inventory estimate of 13,000 kg for the CUs dredged in Phase 1. After adjusting the original mass for setbacks around obstructions and changes in bathymetry, the Total PCB mass removed (20,000 kg) is roughly 1.75 times the adjusted inventory estimate of 11,400 kg.

- PCB-contaminated wood debris is present throughout the river and was observed in essentially all Phase 1 CUs. CUs at the northern end of the Thompson Island Pool had more debris than those in the southern end of the Pool, but it is anticipated that wood debris will be encountered frequently in the Pool during the Phase 2 areas.

- The viability of "fine grading" (*i.e.,* dredging in thin lifts of 3 inches or less, or to an assigned DoC line without an overcut, see GE letter to EPA, August 13, 2009, provided in the Common Appendix) was not borne out by the large number of dredging passes. The high degree of variability in the actual DoC surface precludes this approach to dredging. The dredging contractor ultimately spent too much time trying to meet the initial design cut line (which proved to be an underestimate of DoC) to the required tolerance of ±3 inches. It would have been more efficient and productive to require a 9-inch overcut in addition to the design cut line and relax tolerances to speed the dredging and closure of the CUs.

- The lack of DoC characterization via each post-dredging coring round resulted in uncertainties in defining the next dredging pass that ultimately limited the ability to remove all inventory in 2 passes. Since post-dredging cores were analyzed incrementally (beginning with only the top 0-6 inch segment) after each dredging pass, the magnitude of the underestimate of DoC could not be rapidly identified and proactively addressed.

- Some capping took place because of the navigation schedule (*e.g.,* CUs 1, 4, and 8) and not because residual sediment contamination was inaccessible (*e.g.,* CUs 5 and 6).

- Capping covered 36 percent of the original Phase 1 areas. Excluding the CUs associated with the debris-laden navigation channel on the east side of Rogers Island as atypical, capping occurred in 18 percent of the remaining CU areas.

- Much of the capping that occurred in CUs 5, 6, 7 and 8 was eventually covered by several feet of additional backfill as part of habitat restoration in these areas. As a result, these capped areas do not represent a significant loss of river bottom habitat due to sediment type change.

- Only about 8% of the total volume removed was actually residual contamination.

- Dredging passes were rapidly completed once decanting and "fine grading" (time spent cleaning the surface to meet the ±3 inch design tolerance) were limited, based on the faster dredging pass times achieved later in the Phase 1 project.

- The calculation process to identify nodes for re-dredging also resulted in a shift in the horizontal extent of the areas identified from dredging pass to dredging pass in some instances, creating some difficulties in dredging pass planning. Occasionally, nodes initially identified as compliant were later found to be non-compliant and required either dredging or in some cases capping. For Phase 2, it is recommended that re-dredging be confined to the area initially identified as non-compliant until the CU complies with the Residuals Standard.

- EPA review of CU certification materials and decisions were typically conducted immediately upon delivery during daily 4:00 PM meetings with GE. Occasionally, additional review time was necessary, but these reviews were completed within 24 hours, thus not adding substantially to the dredging schedule.

Summary of Productivity Standard Implementation

While the actual volume removed during Phase 1, exclusive of access and navigational dredging, was estimated at 273,600 CY by EPA and 282,900 CY by GE, only 10 of the 18 CUs targeted for dredging in Phase 1 were completed. The difference between the dredging project, as designed, and the Phase 1 implementation can be attributed to an underestimation of the actual depth of contamination (DoC) in each CU. During Phase 1, larger volumes than anticipated in the design were removed from each CU dredged. If CU-1 is excluded from the calculation as an anomaly, the average volume actually dredged at each CU was approximately 1.6 times that anticipated during the design.

A new estimate of the total volume remaining to be dredged was needed to support a valid analysis of the prospects for meeting the Productivity Standard in Phase 2 under the current design. Since the Phase 1 results indicated a consistent underestimate of DoC in each CU, two estimates of the potential additional volume that may require dredging during Phase 2 were prepared. Both approaches assumed that the large overrun in quantity in CU-1 was an anomaly. The first estimate applied a factor of 1.6 (incorporating the median increase from design volume encountered during Phase 1) and the second estimate is based on increasing the design estimate of the DoC by approximately 1.13 feet, the average increase in the DOC as found during Phase 1.

The design dredging volume for both Phases 1 and 2 was 1,795,000 CY, which is about 68 percent of the total ROD-estimated dredging volume of 2,650,000 CY that was utilized in the Productivity Standard. The re-estimates of dredging volume, based on experience gained during Phase 1, yield estimated dredging volumes of 2,600,800 to 2,872,000 CY, which are still very close to the original dredging volume estimated in the ROD. As a result, the original Productivity Standard volume of 2,650,000 CY for both Phase 1 and Phase 2 has been utilized in evaluating GE's ability to complete the project over the five years of Phase 2. Further refinement of design dredging volumes should be conducted successively as Phase 2 of the project is planned and implemented.

GE's Weekly Productivity Summary Reports indicate that many hours of potential dredging time were lost during Phase 1 due to:

- Circumstances that can be controlled or mitigated:
  - A shortage of empty hopper scows.
  - The practice of allowing free water to drain from the dredged bucket before placing sediment into the mini-hopper scows due to their limited capacity.
  - The consumption of a significant amount of time while the dredge operators conducted fine grading operations at the end of each dredging pass to meet tight vertical tolerances specified, often times only to find that the inventory was significantly deeper and that additional passes would be required to remove it.
  - Time spent in preparing bathymetric maps, sampling, designing new cut lines and obtaining EPA's approval of new cut lines to remove previously unidentified contaminated sediment inventory following completion of the dredging to the depths shown in the initial design.
- Circumstances that cannot be controlled:

- High river flows that prevented dredging.
  - Storms/inclement weather.
  - The presence of bedrock in close proximity to the dredging cut line.
- Circumstances that may or may not be controllable:
  - Suspension of dredging due to action required by the Resuspension Standard.
  - Dredge buckets that do not completely close due to the presence of woody debris.

Based on information provided by GE, the total time that all dredges working on the project were available and ready to dredge amounted to 18,125 hours over the entire season. This represents the total number of hours available to dredge (fully staffed and fueled, ready to dredge), not the number of hours that dredging actually took place (somewhat less), nor the number of hours that dredges were present at the project (much larger). Of 18,125 available hours, an estimated 10,878 hours (or 60 percent) was spent in active dredging, while the estimated total available dredge production time lost amounted to 7247 hours, or about 40 percent of the time that dredges were available to work.[2]

Out of the 18,125 hours available for dredging, an estimated 382 hours (2 percent) were lost due to lightning storms, fog or other inclement weather conditions, 1022 hours (6 percent) due to concerns about high concentrations of PCB in the water column, 1090 hours due to high flows (6 percent), and 4753 hours (26 percent, and by far the largest fraction of the total) were lost due to a shortage of empty hopper scows.

Dredging was completed in 48.3 acres of the approximately 90 acres targeted for Phase 1. Backfill was placed over approximately 31 acres and engineered caps were constructed over approximately 17.3 acres. Backfill and capping materials were placed to within the tolerances specified in the design without undue difficulty. Some problems encountered during backfill work were due to backfill gradations that were not appropriate to maintaining stable slopes in near-shore environments, and the gradation and utility of Type 1 backfill should be reevaluated for Phase 2. Due to deeper than anticipated DoC, the volume of backfill required to achieve submerged aquatic vegetation reconstruction design elevations increased significantly in some CUs. Deeper than anticipated backfill also complicated the anchoring of biologs called for at some shoreline stabilization locations, and alternative approaches for constructing wave breaks and installing biologs and geotextiles at riverine fringing wetlands should be explored for Phase 2.

[2] GE's compilation lists 779 hours of available time lost as dredge operators attempted to remove a thin layer of sediment overlying an uneven clay surface. However, since these hours were actually spent in dredging, albeit at a slow rate of production, they have not been included in a summation of "lost" time.

The disposal of dewatered sediment encountered several unexpected problems during Phase 1, all of which occurred at the disposal facility. The problems included: rail car unloading, rail car cleaning prior to return shipment, and a disposal cell slope failure. It is likely that these concerns can be addressed prior to Phase 2, such that rail cars can be loaded and dispatched from Fort Edward, and unloaded at the disposal facility, at a rate sufficient to handle the estimated sediment volumes to be dredged each year during Phase 2.

While some problems were encountered and lessons learned during Phase 1, there is every indication that if Phase 2 activities are planned appropriately (*e.g.*, an adequate number of empty scows is made available), the project can achieve the Phase 2 productivity targets. The maximum amount dredged during any one month period in Phase 1 was estimated at 78,000 CY; however, had empty scows been available and had the dredgers not expended additional time attempting to meet the tight vertical tolerances specified for the dredge cut between multiple dredging passes, it is likely that the Phase 1 dredging production could have exceeded the monthly amount required to meet Phase 2 targets.

The following additional recommendations are provided for Phase 2:

- Steps should be taken to better define DoC for Phase 2 to minimize the number of dredge passes needed to remove missed inventory. For example, in locations where clusters of SSAP cores are incomplete, additional probing and coring should be considered to refine the design in the season prior to dredging those areas.

- Post-dredging core samples should be collected <u>prior</u> to, rather than after, conducting fine grading of the river bed, if performed, to correct areas where the cut line was found to be slightly higher than the design cut line. During Phase 1 there were many cases where post-fine grading sampling indicated significant additional inventory below the design cutline which effectively meant the fine grading step was unnecessary or at least highly inefficient. Sampling prior to fine grading would address this inefficiency and minimize the need for fine grading.

- Dredging necessary to gain access to a CU should be conducted immediately prior to dredging that CU so that the dredge platforms and scows can operate efficiently.

- Heavy duty environmental buckets capable of shearing through wood debris and closing more quickly and frequently should be obtained, if available.

- Draining free water from closed dredge buckets increased cycle time and should be prohibited during Phase 2. Other methods should be considered to control excess water in mini-scows.

- Scows should be loaded to their maximum capacity, consistent with vessel stability, during Phase 2. The average volume of solids carried in a large hopper scow during Phase 1 was 421 CY; the maximum volume of solids recorded in a scow was 929 CY.

- Changes to scow unloading systems and coarse materials separation systems are needed to ensure that Phase 2 production rates are met. Options that might be considered include the addition of a second unloading station and the use of shaker screens rather than the trommel screen currently in use for initial separation of coarse sediments. Large balls of clay should be handled separately from other materials.

Recommendations and Proposed Changes to the Standards

Based on the experiences of Phase 1 and lessons learned, changes to the dredging design and implementation to improve compliance with the Engineering Performance Standards are recommended for Phase 2 as described above and in each of the major chapters of the report. Changes are also recommended to some aspects of each of the Engineering Performance Standards to optimize the outcome and enhance the ability of the project to consistently meet the standards simultaneously. These changes are described in the major chapters, and compiled in Chapter IV. A concise summary of these changes, along with the underlying rationale and an assessment of impacts of the changes on the other standards is presented in Table Intro-1.

INTRODUCTION REFERENCES

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CHAPTER I
EVALUATION OF THE RESUSPENSION STANDARD IMPLEMENTATION

CHAPTER I – EVALUATION OF THE RESUSPENSION STANDARD IMPLEMENTATION

CHAPTER I SUMMARY

The Engineering Performance Standard for Dredging Resuspension (Resuspension Standard; USEPA 2004, Volume 2) was designed to monitor and control PCB concentrations in the water column of the Hudson River during dredging activities. Its primary objectives were to create a framework to maintain PCB water column concentrations below the United States Environmental Protection Agency's (EPA's) 500 nanogram per liter (ng/L) Safe Drinking Water Act Maximum Contaminant Level (MCL) and to minimize the release of PCBs from dredged sediments and control their long term downstream transport. The criteria included in the Resuspension Standard were developed from the federal drinking water MCL, mass export rate, baseline monitoring data, and an estimate of the total mass of PCBs to be removed from the Hudson River during the project. The Resuspension Standard functioned as designed during Phase 1, and monitoring data collected were used to temporarily halt dredging operations when the 500 ng/L criterion was exceeded on three occasions. According to GE's estimates, these temporary operational halts consumed less than 6 percent of the available dredging hours and so EPA concludes they did not have a major impact on the ability to meet the Productivity Standard. Since dredging activities ended, water column concentrations have returned to baseline levels at all far-field stations. The field observations and sample analytical data gathered during Phase 1 have led to an enhanced understanding of the impact of dredging operations on the Hudson River water quality, as summarized below.

Low Suspended Solids Concentration Observed During Dredging

Suspended solids concentration was not a good predictor for Total PCB transport downstream of the dredging operations. Special studies show that PCBs in the vicinity of the dredge operations were dominated by dissolved and Non-Aqueous Phase Liquid (NAPL) phases. There was no significant downstream transport of solids beyond the immediate vicinity of the dredging operation, based on total suspended solids (TSS) measurements. Average TSS concentrations at near-field monitoring stations were well below the evaluation criteria of 700 mg/L at 100 m and 100 mg/L at 300 m downstream of the dredging operations.

Multiple Factors Controlled Far-field PCB Transport During Dredging

The impact of dredging cannot be predicted by mass removed and river flow/velocity alone. Statistical analyses indicate that several processes may have contributed to the PCB transport to the far-field at Thompson Island. The most likely factors that contributed PCBs to the water column are not unexpected—mass and volume removal, vessel traffic, disturbance of exposed contaminated surface sediments, processes associated with backfilling, and the extent to which dredge buckets may be overly full or dredging is hurried. A statistical model accounting for these variables can explain about 60 percent of the variability in water column PCB concentrations at Thompson Island during dredging. The following field observations provide further support for the premise that a multitude of factors contributed to water quality impacts:

- Release of PCB-bearing oils from the sediments during dredging. These oils were observed as sheens on the water during oversight and were also sampled and analyzed during Phase 1; however, the oils were not isolated for analysis such that a specific congener pattern could be identified. The presence of free product oil also likely hampered the collection of precise field replicates during Phase 1. The presence of oil was likely responsible for the factor of 3 or greater differences in sample replicates when concentrations approached the 500 ng/L threshold.
- Boat traffic associated with the dredging as well as other activities. Observable spikes in water column PCB concentrations in the far-field were associated with a barge that was accidentally grounded, a tragic boating accident, and other high vessel traffic events.
- Decanting of water from dredge buckets directly into the river. Water contained with the sediment was extensively allowed to drain back to the river, potentially releasing interstitial dissolved PCBs as well as interstitial PCB-bearing oils.
- Spillage from partially-closed dredge buckets (where debris interfered with bucket closure). Both suspended solids and interstitial fluids could be released in this manner.
- Debris removal to address smaller obstructions. Debris removal took place at the beginning of the operation to remove large objects identified on the river bottom. However, subsequent debris removal attempts did not remove substantive amounts of debris but did serve to disturb and resuspend sediment.
- Non productive clean-up passes (fine grading of the sediment surface to meet close dredging tolerances), causing resuspension with little net sediment removal.

<u>Fish Tissue Impact Limited to the Vicinity of Dredging</u>

Some increases in fish tissue PCB levels were seen in 2009 within the Upper Hudson River when compared to baseline data. The increases in fish tissue PCB levels were predominantly identified in the Thompson Island Pool (i.e., the section of the river where the Phase 1 dredging occurred), with limited evidence of responses downstream. There were no statistically significant increases in fish tissue PCBs at the Albany/Troy lower river monitoring station below the Federal Dam at

Troy. Overall, the monitoring data indicated that resuspension of PCBs from sediments during dredging affected fish locally, with greatest impact in the immediate vicinity of the dredging activity, but the current data do not support the notion that dredging had an effect on PCB levels in fish more than 2 to 3 miles downstream of the Thompson Island Pool.

Net PCB 7-day Running Average Load Criteria Exceeded

For the majority of the project, the 7-day running average net loadings for Total PCBs (TPCB) and Tri+ PCBs at Thompson Island exceeded the Control Levels of 1,080 g/d and 361 g/day, respectively. After October 27, 2009, the daily average TPCB load at Thompson Island decreased, but estimates were still above the evaluation criteria of 540 g/d. This period coincides with backfill and cap placement and increased vessel movement.

At Waterford, the 7-day average load was less than the Evaluation Level about 50 percent of the time and exceeded the Control Level 20 percent of the time.

Seasonal PCB Load Control Levels Exceeded

The Resuspension Standard seasonal PCB load control levels for both TPCB (117 kg) and Tri+ PCB (39 kg) were exceeded at all of the downstream monitoring stations. Between May 15 and November 30, 2009, the cumulative load at Thompson Island of 437 kg was about 1.5 times higher than the load at Lock 5 (269 kg/yr) and about 3 times higher than the export TPCB to the Lower Hudson at Waterford (151 kg/yr). While elevated, the 437 kg estimated load for Thompson Island is small relative to the mass of PCB removed (20,000 kg). Tri+ PCB cumulative loads estimated for Lock 5 (123 kg/yr) and Waterford (61 kg/yr) exceeded the Control Level of 39 kg.

However, the cumulative loads of TPCB at Waterford, which is the station of importance with respect to downstream impact, did not exceed 1 percent of the mass removed during Phase 1 (*i.e.,* 200 kg for TPCB).

Low PCB Export Rate to Lower River

The PCB mass loss varied between 1 to 2 percent on a weekly basis at Thompson Island. The mass of PCB lost to the Lower Hudson River during most of the dredging period, as estimated at Waterford, was less than 1 percent. Therefore, EPA's goal of a 1 percent loss rate to the Lower Hudson River was achieved.

No Impact of Sediment Redistribution During Dredging

Data do not support the notion that settling of PCB-contaminated sediment was a significant contributor to resuspension and recontamination of non-dredged areas. Because of the baseline dynamics of sediment movement in the river and the high degree of variability in co-located sediment concentrations, investigations during dredging indicated that sediment redistribution is unlikely to affect broad areas of the river bottom. Post-dredging water column PCB concentrations have returned to baseline levels providing further support to the fact that redistribution of contaminated sediments did not impact the river.

No Dredging Impact in the Lower Hudson River

Water column concentrations in the Lower Hudson River did not increase in response to loads from the Upper Hudson. In particular, there were no discernable increases in Total PCB or Tri+ PCBs at the Lower Hudson monitoring locations near Poughkeepsie, Port Ewen or Rhinebeck. Tri+ PCB concentrations were also unchanged at the Albany monitoring station, roughly 15 miles downstream of Waterford.

Evidence for Revising PCB Load Criteria

The PCB load component of the resuspension standard was not intended to accelerate natural attenuation of PCB problems in the lower Hudson River, but rather to ensure that the remediation of the Upper Hudson River did not worsen conditions in the Lower Hudson River over the long term. During Phase 1 dredging, the loads in the Upper Hudson River were higher than expected. The effect of this was seen in higher water column samples at Thompson Island. However, in spite of these increased loads the fish tissue concentrations 2 to 3 miles downstream of Thompson Island were largely unaffected. Also, prior modeling analysis indicates that the effects of PCB releases due to dredging will be limited to short term impacts.

The observed baseline loads to the Lower Hudson prior to dredging were substantially greater than the model forecast of Monitored Natural Attenuation (MNA) and show very little decline. The loads to the Lower Hudson River under MNA will be substantially greater than those forecast by the model by approximately 6,000 kg over 25 years. Also the surface sediment concentrations in the Upper Hudson River remain elevated despite the passage of time and continue to provide a greater reservoir of contaminated sediments for transport to the Lower Hudson than was envisioned when the remedy was selected. These observations provide further impetus for the remedy and revising the PCB load standard to account for the PCB mass removed and the resuspension observed in Phase 1.

Considerations for Setting a Revised Load Standard

The analysis presented in Section 3.3.9 and Appendix I-G describe a scenario wherein roughly 1 percent of the current PCB mass of contaminated sediments slated for remediation is lost to the Lower Hudson River. The cumulative loads under this scenario are contrasted with those delivered under MNA. The result of this comparison indicates that a dredging-related load of this magnitude will be offset by the ensuing reduction in MNA loads with no long term impacts to the Lower Hudson. This load analysis yields a much higher load criterion to the Lower Hudson than in the original Resuspension Standard and reflects the significantly greater MNA loads and Upper Hudson PCB inventory than were estimated when the standards were first developed.

While EPA proposes to set the acceptable dredging-related loss to the Lower Hudson at roughly 2,000 kg at Waterford for the duration of the project, the proration of this load over time and to the upper river monitoring locations is still under development. EPA expects to complete this analysis in April 2010 and will at that time provide its conclusions in the form of an addendum to this report. The proration will consider a number of concerns, based in large part on the observations of Phase 1. These include:

- The observed 3-fold decline in dredging-related PCB load from Thompson Island to Waterford. This decline provides a basis to allow upstream stations to have greater PCB loads relative to Waterford.
- The distribution of the PCB inventory for remediation in the Upper Hudson. More than 80 percent of the inventory is located upstream of the Schuylerville station.
- The goal of minimizing exceedances of the 500 ng/L water column standard in the Upper Hudson.
- Reduction to the extent possible of dredging-related loads based on future improvements to the dredging operations. As described in Appendix I-G, EPA is currently developing a model relating various dredging parameters to far-field water column concentrations. The recommendations from the model analysis as well as other recommendations in this report should serve to measurably reduce the rate of PCB loss.

Revisions for Phase 2

The seasonal Total and Tri+ PCB loads and the corresponding Evaluation and Control Level loads need to be adjusted upward for Phase 2 to permit completion of the remedy in a reasonable time frame while reflecting the substantially greater baseline loads as well as the new, significantly larger estimates of the amount of inventory to be removed.

The Resuspension Standard allowed refinements to the load-based criteria (USEPA, 2004; Vol.1, Section 4.0). Specifically, these criteria in the Resuspension Standard were to be reviewed and refined if the estimate of PCB mass to be removed is significantly different from previous estimates. In fact, the extensive sediment sampling database developed during the design and during the Phase 1 dredging program clearly documents that the mass estimate to be removed is significantly different than anticipated at the time the standard was developed. EPA is not proposing to change the acceptable rate of loss (1 percent) or the acceptable water column concentrations, but as allowed by the Standard, EPA is applying the acceptable rate of loss to the revised estimate of mass to be removed in revising the load-based criteria. A preliminary load criterion of 2000 kg at Waterford is proposed, representing roughly 1 percent of the current inventory estimate. This load criterion will be prorated over time and for the upstream stations. It may also be adjusted as estimates of the PCB mass to be removed are further refined. The load criteria will be presented in the April addendum

Additional controls should be implemented during Phase 2 to mitigate sources of PCBs to the water column based on lessons learned during Phase 1:

- The effectiveness of various absorbents to capture oil sheens should be investigated and the selected control should be deployed around each dredge. This investigation should consider absorbent curtains that can be anchored to the river bottom to provide containment.
- The practice of draining free water from dredge buckets into the Hudson River should be curtailed to reduce dissolved and NAPL phase releases to the water column.
- Dredging-related vessel and tug movement should be minimized during dredging, especially in shallow areas where there is high potential to disturb sediment.
- Debris removal should be limited to one pass for large objects. During Phase 1, subsequent debris passes yielded little debris but disturbed the sediment; these should be avoided for Phase 2.

1 OVERVIEW OF THE RESUSPENSION STANDARD FOR PHASE 1

This section provides an overview of the Resuspension Standard. The standard is comprised of an absolute water concentration threshold as well as several other criteria against which PCB concentrations, PCB loads, and suspended solids levels are compared. In addition to these criteria, the standard also establishes monitoring requirements and the required or recommended responses. Note that the original peer-reviewed seasonal and daily load criteria and the standard monitoring requirements were slightly modified during the remedial design period in response to changes in monitoring implemented by the General Electric Company (GE). These modifications were the result of the following: (1) an increase in the targeted PCB mass removal in Phase 1 from 10 percent to 18 percent of the total inventory estimated to be removed; (2) the introduction of automated sampling systems; and (3) changes in conditions related to the availability of alternate water supplies to the downstream public water intakes. The standard is briefly outlined here, incorporating these modifications.

1.1 Statement of the Resuspension Standard for Phase 1

The Resuspension Standard has a maximum allowable TPCB concentration in the water column of 500 ng/L (*i.e.,* 500 parts per trillion), regardless of the source of the PCBs. Water quality monitoring conducted at a group of established stations in the river located at least one mile downstream of the dredging activity (referred to as the "far-field" stations) were used to evaluate compliance with the standard. The 500 ng/L concentration is the EPA's MCL for PCBs in drinking water supplies. Potential sources of PCBs to the water column during the remediation include the impacts from dredging, debris removal, installation and removal of resuspension controls, dredging-related vessel movement, non-project-related vessel movement, and flow fluctuations in the river from upstream non-dredging sources. As described in the Resuspension Standard, dredging was allowed to proceed only when the concentration of TPCBs in the river water at any Upper River far-field station was 500 ng/L or less.

1.2 Objectives

The objectives of the Resuspension Standard (as stated in Resuspension Standard, Volume 1, p. 37) were to:

- Maintain PCB concentrations in the water column at or below the federal drinking water MCL of 500 ng/L to protect downstream municipal intakes.
- Minimize the release of PCBs from sediment during remedial dredging.
- Minimize the export of PCBs to downstream areas, including the Lower Hudson River.

In order to meet the objectives of the Resuspension Standard, EPA designated threshold action levels to trigger contingency monitoring and engineering evaluation and controls to reduce the release of PCBs from dredge areas. The Resuspension Standard specified three action levels: Evaluation Level, Control Level, and Standard Level (as described in the Resuspension Standard, Volume 2, Section 4.1). These action levels apply to PCBs and/or TSS in surface water at near-field monitoring stations located 300 meters (m) downstream of a dredging operation or 150 m downstream from a suspended solids control measure (*e.g.,* silt curtain), and at far-field stations located more than one mile downstream of the dredging activity. The Resuspension Standard specified the routine water quality monitoring program designed to verify that the objectives of the Resuspension Standard are being met during dredging and indicated the required additional monitoring or contingency actions if these action levels are exceeded.

The applicable action levels in the near-field and far-field monitoring (as summarized in Table 2 of Volume 1 of the Resuspension Standard) were modified as specified in Appendix A to

Consent Decree Modification No.1; see Table I-1-1. The modifications resulted in a revised water monitoring program that reduced or eliminated the need for increased monitoring at the Evaluation and Control action levels; these revisions are part of the modifications to the peer-reviewed standard monitoring requirements as discussed in Section 1. However, exceedance of some of the action levels still required contingency monitoring under the modified program. Some of the revisions to the monitoring program were designed to reduce the complexity of manual sampling (*i.e.,* through the introduction of autosamplers) and the logistical challenge of staffing and managing a monitoring program with criteria-based sampling frequencies, while other modifications resulted from the potential for downriver water suppliers to access alternate non-Hudson River water sources at need. Note that this revised program did not compromise any of the monitoring goals set forth in the standard; instead, the introduction of autosamplers represented an enhancement to the program and allowed for more representative sampling of the river water column. In fact, the Resuspension Standard envisioned that autosamplers would be evaluated during Phase 1 for use in Phase 2. The revised monitoring program is described in detail in the Phase 1 Remedial Action Monitoring Quality Assurance Project Plan (RAM QAPP; GE, 2009a) and the Performance Standards Compliance Plan (PSCP; GE, 2009b).

1.3 Near Field Criteria

There were two near-field action levels as summarized in Table I-1-1: the Evaluation Level and the Control Level.

The Evaluation Level for Phase 1 included:

- A net increase in TSS concentration of 100 mg/L above ambient (upstream) conditions at a location 300 m downstream of the dredging operation or 150 m downstream from any suspended solids control measure (*e.g.,* silt curtain). Under the revised monitoring program, this criterion was based on a six-hour average concentration, as measured in 6-hour composited samples collected by automated sampling stations.

- The sustained TSS concentration of 700 mg/L above ambient (upstream) conditions at near-field stations located to the side of dredging operations or the 100 m downstream of dredging operations. Under the revised monitoring program, achievement of this criterion was assessed by comparison to TSS concentrations calculated from turbidity measurements made twice per day on transects located parallel to the direction of flow approximately 10 meters from the dredging operation and perpendicular to the flow about 100 meters downstream of the dredging operation (or 50 meters downstream of the most exterior resuspension control system), using a TSS-turbidity relationship. This assessment, based on calculated TSS concentrations, was verified by TSS concentrations measured in grab samples collected during these transect runs (2 per day) from points on these transects that correspond to the highest turbidity measurement (or at certain specified locations in the event that a peak in turbidity is not observed).

The near-field Control Level was the same as the first of the above Evaluation Level criteria: a net increase in TSS of 100 mg/L in comparison to ambient, represented as a 6-hour average concentration as measured in a 6-hour composited sample.

1.4 Far-Field Criteria

There were three far-field action levels: the Evaluation Level, Control Level and Standard level. The standard included action levels based on PCB loading, PCB concentrations, and TSS concentrations. The Resuspension Standard allowed the PCB loading criteria to be adjusted for Phase 1 if targeted Phase 1 production differed from the assumptions on which those criteria were based (Resuspension Standard, Volume 2, p. 97); such adjustments were made as described in Attachment A to Consent Decree Modification No 1 (Table I-1-1). The estimate of the mass inventory to be removed was approximately 70,000 kg as developed in the Feasibility Study (USEPA, 2000). The projected load was set at just below 1 percent of this total or 650 kg. Originally, the ROD estimated that 10 percent of the total mass was to be removed in Phase 1, or 65 kg (650 multiplied by 0.10). Based on the remedial design for Phase 1, it was determined that dredging of Phase 1 areas would remove approximately 18 percent of the mass (not the 10 percent originally estimated); as a result the mass load number was adjusted to 117 kg (650 multiplied by 0.18) for TPCB and 39 kg for Tri+ PCB. While this slight adjustment was made, the larger adjustment to total load criteria (650 kg) was not made at this time, even though the design data indicated a significantly higher mass inventory of PCBs to be removed (115,000 kg). The remedial design inventory was estimated to be 115,000 kg TPCBs (Phase 2 Dredge Area Delineation Report; GE 2007) prior to Phase 1 dredging activities.

For Phase 1, the Evaluation Level criteria are as follows:

- The Resuspension Standard provided (Volume 2, pp. 87, 89) that the Evaluation Level would be exceeded if "[t]he net increase in TPCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 300 grams (g)/day for a seven-day running average" or "[t]he net increase in Tri+ PCB mass transport due to dredging related activities at any downstream far-field monitoring station exceeds 100 g/day for a seven-day running average." Given the adjustment to the Control Level PCB loading criteria discussed below, these Evaluation Level criteria were correspondingly adjusted for Phase 1 to 541 g/day for TPCBs and 180 g/day for Tri+ PCBs, which represented half of the adjusted 7-day average daily load criteria under the Control Level.

- The Resuspension Standard provided further (Volume 2, p. 89) that the Evaluation Level would be exceeded if the TSS concentration above ambient (upstream) conditions at a far-field station exceeded 12 mg/L. Under the revised monitoring program, this criterion was based on a 24-hour average concentration, and achievement of this criterion was assessed by comparison to TSS concentrations measured in 24-hour composited samples collected at the automated far-field sampling stations.

For Phase 1, the Control Level criteria are as follows:

- As provided in the Resuspension Standard (Volume 2, p. 93), the Control Level would be exceeded if "[t]he TPCB concentration during dredging-related activities at any downstream far-field monitoring station exceeds 350 ng/L for a seven-day running average."

- The Resuspension Standard also provided (Volume 2, p. 95) that the Control Level would be exceeded if "[t]he net increase in PCB mass transport due to dredging-related activities measured at the downstream far-field monitoring stations [for the entire season] exceeds 65 kg/year Total PCBs or 22 kg/year Tri+ PCBs." However, the Resuspension Standard allowed these overall seasonal criteria to be adjusted for Phase 1 if the targeted Phase 1 mass removal differs from the assumptions on which those criteria were based – which was that 10 percent of the TPCB inventory subject to removal would be dredged in Phase 1 (Resuspension Standard, Volume 2, pp. 95, 97). As noted previously, it would have been also appropriate to revise the 650 kg TPCBs resuspension standard based on the substantially larger total mass inventory that was developed during the remedial design, thereby resulting in a mass loading rate much greater than 65 kg; however, GE did not request this modification. Comparing the TPCB mass in all dredge areas (as calculated in GE's Phase 2 Dredge Area Delineation Report; GE 2007) to the mass targeted for removal in Phase 1 indicated that the PCB mass targeted for removal in Phase 1 was actually 18 percent of the total inventory estimated to be removed. Based on these estimates, using an equation presented in the Resuspension Standard (Volume 2, p. 97), these criteria for the total net increase in PCB loading in Phase 1 due to dredging-related activities, as measured at the downstream far-field monitoring stations, were adjusted to 117 kg/year of TPCBs and 39 kg/year of Tri+ PCBs.

- The Resuspension Standard provided (Volume 2, p. 93) that the Control Level would be exceeded if "[t]he net increase in TPCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 600 g/day on average over a seven-day period," or "[t]he net increase in Tri+ PCB mass transport due to dredging related activities at any downstream far-field monitoring station exceeds 200 g/day on average over a seven-day period." Given the above-described adjustments to the seasonal load criteria, these seven-day average daily load criteria were correspondingly adjusted for Phase 1 to 1,080 g/day for TPCBs and 361 g/day for Tri+ PCBs, based on the fact that the estimated TPCBs mass targeted for removal changed from 10 percent to 18 percent for Phase 1.

- Another Control Level criterion stated in the Resuspension Standard (Volume 2, p. 94), concerns the TSS concentrations. The Control Level would be exceeded if the TSS concentration above ambient (upstream) conditions at a far-field station exceeded 24 mg/L. Under the revised monitoring program, this criterion was based on a 24-hour average concentration, and achievement of this criterion was assessed by comparison to TSS concentrations measured in 24-hour composited samples collected at the automated far-field sampling stations.

Under the Resuspension Standard (Volume 2, p. 98), the Standard Level is "a confirmed occurrence of 500 ng/L TPCBs, measured at any main stem far-field station." As documented in the Resuspension Standard, exceedance of the Standard Level must be confirmed by four six-hour samples collected once a concentration greater than 500 ng/L TPCBs was detected. The Standard Level was exceeded if the average of the five sample concentrations (*i.e.,* the original 500 ng/L occurrence and the four subsequent confirmatory samples) was greater than 500 ng/L TPCBs. Under the revised monitoring program, to exceed the Standard Level threshold (which remained at 500 ng/L TPCBs under the revised program), an initial result greater than or equal to 500 ng/L TPCBs must have been confirmed by the average concentration of triplicate samples collected within 24 hours of the first sample. Under the revised monitoring program, notification to EPA, NYSDEC, NYSDOH, and the downstream public water suppliers was to be made if a concentration at or above 500 ng/L was reported in any single sample. The standard threshold does not apply to far-field station measurements if the station is within one mile of the dredging.

1.5 Review of the Development of PCB Load Criteria

The PCB mass load export was part of the resuspension discussion in the Record of Decision (ROD) because of its potential to impact areas downstream of the dredging including the Lower Hudson River. While a mass load limit was established for each of several downstream sampling locations, it was primarily established to limit the mass being transported into the Lower Hudson, beyond the furthest downstream sampling station (located at Waterford, approximately 30 miles downstream of Phase 1 areas). In particular, the Resuspension Standard defines the net export to the Lower Hudson as the resuspension export rate at Waterford. The load and export rates were not risk derived numbers but based on a 0.5% mass loss (action level) and a 1.0 % mass loss (control level). The modeling work concluded that these export rates would release less PCBs to the Lower Hudson than MNA. Further clarity on the use of export rates is provided below. This is but a portion of the discussion concerning the development of the criteria that appears in Volume 2 of the Engineering Performance Standards.

Volume 2, page 4 of the Engineering Performance Standards discusses the export rate:

> Resuspension export rate - Beyond roughly one mile, further PCB removal from the water column by particle settling becomes small, and most of the PCBs in the water column are likely to travel long distances before being removed or captured by baseline geochemical processes such as volatilization or aerobic degradation. The rate at which PCBs are transported beyond one mile is defined as the *resuspension export rate.* It is this rate of PCB loss, with its potential for downstream impacts that is the focus of the resuspension discussion in the ROD.
>
> PCB loss due to resuspension - For the purposes of this performance standard, PCB loss due to resuspension, as stated in the ROD, is defined as the resuspension export rate just described. The standard addresses the net export of PCBs resulting from any activity related to the removal of PCB contaminated sediments from the river bottom. This definition includes PCB export resulting from the dredging operation itself and from dredging-related boat movements, materials handling, and other activities. This definition requires both the disturbance and the downstream transport of PCBs from the source. An important point is that the standard does not directly address the resuspension release rate or the resuspension production rate. These rates are considered only indirectly to the extent that they produce an export of PCBs beyond a distance of one mile downstream of dredging activity. Similarly, the standard does not regulate resuspension within engineered control barriers (*e.g.*, silt curtains), other than the extent to which resuspension within the barriers results in unacceptable export of PCBs downstream.
>
> Net export of PCBs to the Lower Hudson - The net export of PCBs to the Lower Hudson is defined as the PCB resuspension export rate at the Waterford-Lock 1 Station, *i.e*., the load of PCBs at this location that is attributable to dredging related activities. The Waterford-Lock 1 station was selected because it is downstream of the target areas identified in the feasibility study (FS) (USEPA, 2000) but upstream of the Mohawk River, which was shown to be a minor but measurable source of PCBs to the Lower Hudson River (USEPA, 1997). The Federal Dam, which is the lower boundary of the Upper River, was not chosen because this location is downstream of the Mohawk River.

Further language on Page 16 of Engineering Performance Standards Volume 2 (see below) identifies the export rates chosen for the resuspension standard and translates them to the g/day evaluation and control levels in the standard. The text clearly identifies that the 0.13% continually referred to by GE is not the basis of the Standard, and that 0.5% (300 g/day) and

1.0% (600 g/day) are. These are the export rates used and modeled in Attachment D. The relevant language is:

> By this formula, the three percentages given above (0.13%, 0.36%, and 2.2%) translate to PCB export rates of 6, 17, and 104 grams per hour (g/hour) of dredge operation, respectively. These values are comparable in magnitude to the nominal baseline daily flux of PCBs during the dredging season, generally ranging from 20 to 80 g/hr. Thus, the lower end of the possible export rates will be difficult to observe relative to the magnitude and variability of baseline fluxes as demonstrated in the variations discussed in Attachment A**.** In light of this observation, three nominal resuspension export rates were explored in this analysis: 0.5%, 1.0%, and 2.5%. These translate to 24, 47, and 119 g/hr respectively (or nominally 300, 600, and 1,600 g/day on a 14 hour/day basis).

Volume 2, page 24 states:

> The resuspension scenarios in the foregoing bullets are specified as the PCB export rate at the far-field monitoring stations. Due to the nature of the HUDTOX model structure, PCB loads cannot be readily specified at far-field locations (i.e., specifying the resuspension export rate). Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the local resuspension release rate from the dredging operation; that is, the rate of Total PCB and solids transport at the downstream end of the dredge plume.

And following on that same page, EPA states:

> The Total PCB input loading term for HUDTOX (the resuspension release rate) was derived iteratively so as to obtain the desired PCB export rate at the far-field monitoring location The resuspension release rate was obtained by checking the resuspension export rate (output from HUDTOX) until the model output gave the desired Total PCB export rate.

EPA went on to say in page 25:

> The cumulative Tri+ PCB load at Waterford as forecasted by HUDTOX was used to determine what would be considered a significant release (i.e., resuspension export rate) from the dredging operation.

Page 51 has the following language concerning the development of the load criteria:

In developing the load criteria for the standard, several different perspectives were examined to make the standard meaningful (i.e., not too high) and achievable (i.e., not too low). These include the following:

- Best engineering estimate of resuspension production and export
- Minimum detectable PCB load increase
- Loads defined by the water column concentration criteria of 350 and 500 ng/L Total PCBs
- Impact of load on fish tissue recovery
- Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson (i.e., Waterford load)

Page 54 also discusses the water level criteria:

> A 600 g/day Total PCBs scenario was run, based on its selection as a load criterion (see below). As expected, the 350 ng/L scenario has a greater impact than the 600 g/day scenario. However, both model runs indicate negligible[13] changes in fish tissue concentrations in regions downstream of the dredging. Within five years of the completion of dredging there is little discernable impact from the dredging releases based on the fish tissue forecasts. The model results suggest that compliance with the water concentration criteria previously developed (i.e., 350 ng/L and 500 ng/L) will also minimize dredging impacts to the long-term recovery of the river.

Page 55 presents a footnote that identifies the 1% release rate:

> Also shown on the figure is a forecast curve for a Tri+ PCB load for the 600 g/day scenario, equivalent to 200 g/day Tri+ PCBs[14]. This curve also crosses the MNA forecast, just after the completion of dredging. On the basis of this analysis, both the 300 and a 600 g/day load standards would yield acceptable Tri+ PCB loads to the Lower Hudson.
>
> Footnote 14: This load is equivalent to 130 kg/year of Total PCB and 44 kg/yr of Tri + PCBs, or slightly less than 1% of the estimated mass of Total PCBs to be removed.

Further information concerning the export rate is also found in Attachment D of Volume 2:

Attachment D, Page 1:

> Modeling of conditions expected during dredging operations was undertaken to evaluate the short and long-term effects of remedial activities. Far-field models - consisting of fate, transport and bioaccumulation models - were utilized to measure the long-term effects of dredging and to determine the percent PCB mass loss that will result in unacceptable river recovery and adverse impacts to downstream water supply intakes.

Attachment D, Page 57:

> The Evaluation Level and the load criterion of the Control Level specify the Total PCB load at the far-field monitoring stations and the concentration criterion of the Control Level specifies the Total PCB concentration at the far-field monitoring stations. These resuspension criteria are the targeted export rates.

Tables 33 and 34 of Attachment D also have footnotes that indicate Total PCB flux at the monitoring station based on 1% (600 g/d) and 0.5% (300 g/d), respectively, as the export rate at the monitoring stations.

Finally in EPA's Responses to Comments on the draft Engineering Performance Standards, addressing comments from the Saratoga County Environmental Management County, further clarification is given:

> Comment 11 response: The resuspension releases mentioned here are not used directly. The rate discussed in Attachment D (average source strength) was derived independently using the TSSChem model. The case studies were used to show that the anticipated release rate is reasonable. The distance of the near-field will be refined depending on the results of Phase 1. The distances were only considered close in that they did not represent levels that would be representative of contaminant export, given that additional settling would be expected to occur after 300 feet. These distances are site-specific. For other rivers, the different site conditions (flow rate, sediment type, etc.) could result in different locations for representative near-field and far-field. Note that while the best engineering estimates used in the development of the standard represent an export rate of 0.13 percent, the Action Level criteria of 300 and 600 g/day represent export rates equivalent to 0.5 and 1 percent of the mass of PCBs to be removed.
>
> Comment 12 response**:** The 1 percent release rate would be equivalent to the 600g/day release and the PCB load increase was estimated to be less than 50%**.**

The language highlighted above clarifies that the export rate of 1% mass loss was chosen as a basis for the standard and modeled to confirm that the loss rate would not result in unacceptable recovery for the river. The 1% mass loss was then believed to be approximately equivalent to 650 kg and was expected to deliver less PCBs to the Lower Hudson than the MNA scenario. An analysis of the 1% mass loss rate as it relates to the increased mass found in the system is presented later in this chapter. As discussed below, the total amount of PCBs that would be delivered by the MNA scenario is still greater than the amount of PCBs to be delivered by dredging.

1.6 Dredged-Related Water Quality Monitoring Program

The water quality monitoring program consisted of routine monitoring and contingency monitoring. The routine water quality monitoring program consisted of several components. The term "routine" referred to a level of monitoring to be conducted while the dredging operation was in compliance with the Resuspension Standard and action level criteria. As planned, this monitoring would be performed during dredging and associated operations that have the potential for resuspending a significant amount of sediment. The RAM QAPP specified that at a minimum, monitoring was required for the following remedial operations: dredging, debris removal, cap placement, backfill placement, installation and removal of resuspension control devices other than silt curtains (sheet piling and other structural devices requiring heavy equipment operation and disturbance of the river bottom), and during the off-season to provide a continuation of baseline data.

Details of the planned routine monitoring program (which included near-field sampling, far-field sampling, off-season water column monitoring, processing facility discharge monitoring, and shoreline excavation and restoration) were presented in the RAM QAPP. Table I-1-2 summarizes the data quality objectives and associated measurement performance criteria for these monitoring programs. A summary of the near-field, far-field and off season monitoring programs is described below. Deviations from the monitoring program (as modified) that occurred during Phase 1 dredging activities are discussed in Section 3.

1.7 Near-Field Water Column Monitoring

The Resuspension Standard defined the near-field monitoring area to be in the immediate vicinity of remedial operations, nominally extending from 100 feet upstream to one mile downstream. The objective of the near-field monitoring was to evaluate on a real-time basis whether dredging activities caused near-field TSS to be elevated to an extent indicative of elevated release rates of PCB export from dredging activities. The revised monitoring program in the near-field, which applied to the Northern Thompson Island Pool (NTIP) remedial operation, is summarized in Table I-1-3 and Figure I-1-1. Note that the near-field monitoring of remedial operations in the East Griffin Island Area (EGIA) was designed as part of a special study performed in general conformance with the original near-field monitoring program as outlined in the Resuspension Standard. The near field monitoring program for the NTIP as described in the Resuspension Standard is as follows:

- For the NTIP, except for East Channel of Rogers Island, water quality monitoring was performed at buoys and during boat-based transects.
  - For the buoy-based monitoring, buoys were deployed both upstream and downstream of each dredging operation (or group of operations when located in close proximity to each other). These included a station located 100 m upstream of the dredging operation and a station located 300 m downstream of the dredging operation (or 150 m downstream of the most exterior downstream resuspension barrier). The buoys were equipped with continuous-recording direct reading probes and automatic samplers to collect real-time water quality parameters (e.g., DO, conductivity, temperature, pH, turbidity) and composite TSS samples.
  - For the boat-based transects, monitoring along four transects located in the vicinity of each monitored dredging operation(s) were conducted twice each day. These transects included three bank-to-bank transects (cross-channel) located perpendicular to the direction of flow, and one in-channel transect located parallel to the direction of flow. The cross-channel transects were used to assess water quality entering and leaving the dredge operation being monitored. The in-channel transect attempted to discern resuspension caused by workboats, tug boats, and barges that were providing support for a dredging operation. The cross-channel transects were located approximately 100 m upstream and 100 m and 300 m downstream of the dredging operation(s) (or 50 m and 150 m downstream of containment barriers when used). The in-channel transect was located approximately 10 m from the dredge on the side of the dredge (and associated tug and barge activity) that is adjacent to the edge of the main channel.
- For East Channel of Rogers Island, where isolation by a rock dike at the upstream end of the island and a silt containment system at the downstream end of the island were implemented, the monitoring consisted of:
  - A boat moving along a single transect located about 25 m downstream of the silt containment system, similar to the procedures for the 300 m downstream transect described above.
  - Three monitoring buoys, one located within the contained area in the vicinity of the Washington County Sewer District Wastewater Treatment Plant (WWTP) discharge, and the other two buoys deployed downstream of the silt curtain in close proximity to the transect location. The buoys contained the same equipment and collected data similar to those in the rest of the NTIP.

The planned near-field monitoring requirements and logic flow chart are provided in Figure I-1-1. The figure shows the monitoring parameters planned to be collected during the boat run transect and buoy deployments, how compliance with the near-field action levels was evaluated, and any actions GE would take if the action levels were exceeded.

1.8 Far-Field Water Column Monitoring

The Resuspension Standard defined the far-field monitoring area as that portion of the Hudson River that is greater than one mile downstream from an active dredging operation. Far-field monitoring had the objective of providing the information needed to see that PCBs exported to the Lower Hudson River downstream of Waterford were minimized and drinking water quality was maintained such that PCB concentrations in the water column were at or below the federal drinking water MCL. In addition, the far-field stations were also subject to the action levels specified in the Substantive Water Quality Requirements (refer to Section 2.1.2 of the RAM QAPP). Far-field monitoring was designed to start one week before dredging operations were initiated for Phase 1 and was to continue until water quality returned to average baseline conditions, but no longer than two weeks after dredging operations have ceased.

A summary of the planned far-field sample collection requirements and logic flow chart is presented in Table I-1-4 and Figure I-1-2. Figure I-1-3 shows the planned far-field monitoring locations. As planned in the RAM QAPP, baseline PCB concentrations and loading from upstream of dredging operations were assessed from the upstream stations at Bakers Falls and Rogers Island. Far-field monitoring stations located at Thompson Island, Schuylerville (at Lock 5), Stillwater, and Waterford were used to monitor the water quality impact of the dredging activities. In addition, the far-field monitoring station at Waterford was used to measure loading to the Lower Hudson River. Additional stations were located at Albany and Poughkeepsie to monitor conditions in the lower river. Sampling was also performed at Cohoes to identify any PCB contributions from the Mohawk River to the lower river. The RAM QAPP details the planned sampling methodology, collection frequencies, analytical methods and monitoring contingencies.

1.9 Off-Season Water Column Monitoring

As specified in the Resuspension Standard, after dredging operations have terminated for the season, the far-field monitoring program is to continue until water quality returns to average baseline conditions, but no later than two weeks after dredging operations have ceased. At that time, the off-season monitoring program will be initiated. As summarized in Table I-1-5, the off-season water column sampling will be performed weekly at Rogers Island, Thompson Island, and Waterford (to the extent that weather and river conditions allow), monthly at Bakers Falls and at the Lower Hudson River stations at Albany and Poughkeepsie, and once every other month at the Mohawk River. If PCB loading at Thompson Island is significantly above baseline levels, weekly sampling will be added at Schuylerville.

1.10 Special Studies

As stated in the Resuspension Standard (Vol. 2, p. 118): "The special studies will be conducted for limited periods of time to gather information for specific conditions that may be encountered during the remediation or to develop an alternate strategy for monitoring. Specific conditions may include different dredge types, contaminant concentration ranges, and varying sediment textures." The Resuspension Standard (Resuspension Standard, Vol. 2, p. 118 et seq.) specified the following special studies:

- Near-field PCB Release Mechanism (near-field PCB Concentrations)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the near-field and far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the near-field and far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Automated Monitoring (referred to in the Resuspension Standard as "Phase 2 Monitoring Plan")

The special studies that addressed development of a TSS-surrogate relationship and automated monitoring are described in separate work plans (GE 2005a, 2006). These special studies were completed before dredging started, and the results of these studies were presented in Appendix 20 for the TSS-surrogate relationship and in the Far-field and Near-field Pilot Study DSR (GE, 2009c) for automated monitoring. While contemplated for Phase 2, monitoring using automated samplers was implemented in Phase 1.

As part of the revised monitoring scope, Attachment A to Consent Decree Modification No.1, specified an additional special study to be performed during Phase 1 dredging to evaluate the efficacy of the fixed-point near-field monitoring procedures described in the Resuspension Standard (USEPA 2004, Volume 2). This additional special study was referred to as the Near-field Fixed Point Monitoring in the RAM QAPP.

Details of the planned Near-field PCB Release Mechanism, Non-Target Downstream Area Contamination, and Near-field Fixed Point Monitoring special studies are described in Chapter 9 of the RAM QAPP. Table I-1-2 summarizes the data quality objectives for these three special studies. Table I-1-6 summarizes the planned sampling program for Near-field PCB Release Mechanism and Non-Target Downstream Area Contamination. Note that due to field conditions and some problems that developed, some special studies were not completed as planned. These studies, as implemented during Phase 1, are described in Section 4.0 of this report.

The Near-Field PCB Release Mechanism Study evaluated the extent to which the PCBs released by remedial operations were dissolved or associated with suspended matter. It was assumed that if much of the release was associated with suspended matter, near-field TSS concentrations could be a reliable indicator of PCB releases, and real-time TSS surrogate measurements taken at near-field stations could be used to identify when dredging activities need to be modified to reduce resuspension and to anticipate when elevated PCB concentrations were expected at far-field monitoring stations. The Near-field PCB Release Mechanism study was planned to be conducted at five areas so that a range of dredging conditions could be evaluated – *e.g.,* different sediment types (cohesive and non-cohesive), PCB concentration ranges, and the range of anticipated dredge types. Four of the planned study areas were located in NTIP and one was located in EGIA (Figure I-1-4 and Figure I-1-5, respectively). However, during Phase 1, this study was only performed in EGIA due to project logistics (see Section 4.1.1).

The Non-target Downstream Special Study was to determine the spatial extent, concentration, and mass of Tri+ PCB contamination deposited in non-target near-field areas downstream from the dredged target areas. As planned, each study area was located downstream of a Phase 1 dredging area, and sediment trap collection techniques were used to collect the deposited sediments.

The Near-Field Fixed Point Monitoring Study, using procedures described in the Resuspension Standard (USEPA 2004, Volume 2), was conducted around a single dredging operation throughout Phase 1, initially in the EGIA. This study was designed to examine resuspension-related effects for each operation individually (*e.g.,* inventory dredging, residual dredging, debris removal, backfilling). As the EGIA is relatively small and located on only one side of the river, it was monitored as one operation. Upon completion of the activities in the EGIA, GE was to propose operations within NTIP, for EPA approval, for continuing this special study for the remainder of Phase 1. It was expected that this special study would rotate among the NTIP operations on a weekly basis, to the extent that such operations were otherwise being conducted. However, during Phase 1 this special study was not implemented in the NTIP. The overall goal of this special study was to compare the revised near-field monitoring described above with monitoring specified in accordance with the procedures set forth in Section 2 of the Resuspension Standard.

1.11 Applicability of Water Column Concentration Correction Factors

GE has applied a correction factor to the water column PCB concentrations for 2009. As stated in the approved RAMP QAPP, EPA asked GE to evaluate and update the correction factor, if appropriate. Its application, however, has not been approved by EPA. The correction factor was developed to accurately quantitate the concentrations of co-eluting BZ4 and BZ 10 congeners based on a defined concentration relationship. The correction factor would change if the relationship between BZ4 and BZ 10 changes. Based on the data collected and reviewed by EPA, this relationship has not changed. As the relationship has remained consistent, application of a higher correction factor is not warranted. In addition, additional analyses, including, but not limited to, the analyses discussed below, are needed to further assess this relationship and enable correlation of changes to the correction factor (if any) resulting from in river actions taken, lab variability, or other factors. GE nevertheless has changed (increased) the correction factor that it applies to water samples collected at the Site.

The basic underlying premise of the need to apply a correction factor to sample results is that the ratio of BZ4:BZ10 in HR samples is different than what is found in calibration standards. Historical data show this relationship to be consistently at 3:1 to 4:1 in samples from 1997, 2003 (other than the boat launch samples), and 2009. The correction factors developed to capture this difference and applied to produce accurate sample concentrations were also consistent in 1997 and 2003, at 0.68 and 0.61, respectively. Yet, GE has increased the 2009 correction factor despite the concentration ratio remaining the same. One would expect increasing/changing congener ratios to be the cause of the increased correction factor and thus highlight a compositional change in river samples.

The concentration ratio of BZ4:BZ10 in the boat launch samples used in the 2004 correction factor development study is outside of the ratios historically observed in 1997, 2003 and 2009. The ratio is clearly higher at this location, yet these boat launch samples have no effect on the regression, even when evaluated separately. Thus a compositional change of these 2 congeners in river samples, possibly as a result of actions taken (dredging), would not be observed.

EPA and GE discussed the correction factor on February 26, 2010. During those discussions, the GE team stated that it does not have a clear, direct answer as to why the correction factor was increased in 2009 (0.81). One possibility raised by the GE team was that internal lab variability may be a contributing factor to the change. The extracts used in the development of the 2009 correction factor were produced by NEA over a short period of time (extracts were collected over two weeks during the dredging season). This differs from the development of the 2003 correction factor (0.61) as extracts used then were produced over a longer span of time (up to a year time frame for the collection and analysis of extracts). However, supporting information to substantiate GE's claim of lab variability was not discussed. Typically, lab variability is routinely a minimal contributor to error when compared to the error emanating from the field. It will be necessary to see trend monitoring results of the laboratory QC samples from both the Peak 5 and individual BZ4/10 analyses over time. This would indicate any instrument drift which should then be correlated to bias in the sample data.

2 ESTABLISHMENT OF BASELINE CONCENTRATIONS AND LOADS

2.1 Overview of Baseline Monitoring Program

The Hudson River ROD mandates that monitoring programs be developed. “These monitoring programs should include sampling of water, biota and sediment such that both short- and long-term impacts to the Upper and Lower Hudson River environs, as a result of the remedial actions undertaken, can be determined and evaluated” (ROD, page 99). Baseline monitoring, the first of the mandated programs, is meant to document the condition of the river prior to remediation so that potential impacts associated with the remedy can be determined. The overall goals of the Baseline Monitoring Program (BMP) are to: establish pre-dredging conditions where necessary for use in evaluating achievement of performance standards; and provide data on PCB levels in fish and water to allow the evaluation of changes and recovery trends.

It was initially planned that the manual sampling techniques developed during the BMP would provide the basis for sampling during the Phase 1 remediation with the aim of capturing short-term perturbation, and that a special study was to be performed during Phase 1 to evaluate the use of automated sampling techniques for Phase 2 compliance monitoring. However, during the BMP sampling period, GE conducted a special study of automated sampling techniques, called the Near-field and Far-field Pilot Study, in conjunction with BMP sampling activities, in order to establish that, if employed, automated techniques could provide representative data during Phase 1 dredging (GE, 2009c). This implementation of an automated sampling program resulted in the simplification of the monitoring requirements for Phase 1 dredging.

This Section presents the following:

- The Data Quality Objectives (DQOs) of the BMP Program
- Summary of the BMP Water Column results
- Summary of BMP Fish Tissue results
- Establishment of Mean and Upper Confidence Limit (UCL) TPCB and Tri+ PCB Concentrations for assessing dredge related impacts at TID, Lock 5 and Waterford Far-field Stations.

- Determination of Annual Baseline Load to the Lower Hudson River

2.2 Data Quality Objectives of BMP

The DQOs of the BMP and the measurement performance criteria that describe how each DQO was to be satisfied are summarized in Table I-2-1. In general, the BMP consisted of routine monitoring and special studies designed to meet the DQOs. A detailed description of the complete BMP is provided in the BMP Quality Assurance Project Plan (GE, 2004).

The routine monitoring portion of the BMP included water column sampling conducted to define the spatial and seasonal gradients in PCB concentration and mass load at the following stations: Bakers Falls (RM 197.0); Rogers Island (RM 194.2); Thompson Island (RM 187.5); Schuylerville (RM 181.4); Stillwater (RM 168.4); Lock 1 (RM 159.5); Waterford (RM 156); Mohawk River at Cohoes; Albany/Troy (RM 145); and Poughkeepsie (RM 75). Table I-2-2 provides a brief description of the routine monitoring water column sampling stations, sampling procedures and significance of these locations. Table I-2-3 summarizes the sample type, analyte, and sampling frequency for each station. Note that to provide continuity and allow comparison of BMP data with historical data, during the first year of monitoring samples were collected from the historical sampling locations at Thompson Island Dam (TID-PRW2) and Schuylerville (Rt. 29 Bridge) using techniques consistent with the historical GE sampling program.

In addition to the routine water column monitoring, several special studies were conducted as part of the BMP. These included the following:

- Conducting pseudo time of travel (TOT) sampling at the routine monitoring stations in the Upper Hudson River. The objective of this special study was to assess the value of attempting to sample a single parcel of water as it traverses the Upper Hudson River.

- Conducting a dissolved/particulate PCB study at Thompson Island and Schuylerville stations to confirm whether the PCBs are partitioned between particulate and dissolved phases in the manner observed during the Remedial Investigation studies. The objective of this special study was to obtain knowledge on how PCBs are distributed between particulate and dissolved phases under baseline conditions, providing another means to evaluate the possible cause of elevated PCB levels that may be observed during the remedial action.

- Comparing the PCB data obtained from the Lock 1 station (located above the Halfmoon, NY drinking water intake) with PCB data paired to the samples collected at the Waterford station (located below the Halfmoon, NY drinking water intake) to determine the degree to which they correlate. Essentially, if the two stations were shown to be sufficiently similar, then monitoring and compliance with PCB water quality criteria at Waterford could be protective of water quality at Halfmoon. The objective was to abandon sampling at the Lock 1 station if a strong regression relationship with a slope not different from one and an intercept not different from zero exists between the Lock 1 and Waterford station.

- Performing hydrologic surveys at routine monitoring stations where the sampling type being collected is a cross-sectional composite sample. The objective was to use this data to refine the equal discharge interval locations.

2.3 Summary of BMP Water Column Results

The BMP was conducted from 2004 to 2009, before dredging began in the Upper Hudson River. During this monitoring period, the BMP was modified as specific DQOs were achieved. These modifications are summarized in Corrective Action Memoranda (CAMs) submitted by GE and reviewed by EPA. This section summarizes the BMP results.

2.3.1 Pseudo Time of Travel Events

Pseudo TOT sampling was conducted at the routine monitoring stations in the Upper Hudson River once per month for six months (June through November) during 2004. This special study was performed to assess the value of attempting to sample a single parcel of water as it traverses the Upper Hudson River from Rogers Island (RM 194) to Waterford (RM 156). The TPCB data collected using these TOT sampling techniques showed similar magnitude and spatial and temporal pattern to the data collected using the routine sampling procedures (Figure I-2-1). Based on the observation that the routine sampling procedures characterize current water column conditions and variability, the TOT sampling was discontinued in 2005.

2.3.2 Dissolved Phase/Particulate Phase Partitioning Study

A Dissolved Phase/Particulate Phase PCB study was conducted at the Thompson Island and Schuylerville sampling stations to provide an updated baseline of PCB partitioning between dissolved and particulate phases in the water column. Once per month (June through November) during the 2004 sampling season, high-volume composite samples were collected and field-filtered at each of these two stations. Separate extractions and congener-specific PCB analyses were performed on the filtrate and the particulate matter collected. The organic-carbon-normalized partitioning coefficient, K_{oc}, was estimated for each PCB congener peak quantified by the modified Green Bay Method (Table I-2-4). The results, presented in CAM 3 (GE, 2005b), showed the following:

- As shown in Figure I-2-2, the K_{oc} results show a general linear correlation with published values of octanol-water partitioning coefficient K_{ow} (Hawker and Connell, 1988). The K_{oc}

values tend to plateau at high K_{ow}, consistent with the influence of a third phase, and GE hypothesized that this phase is likely dissolved organic matter. However, as shown in Section 3, this third phase is likely associated with NAPL.

- Similar to patterns observed by USEPA during the RI/FS (USEPA 1997), there is some tendency for values to be higher in the colder months, consistent with the effect of temperature on partitioning.

- Although the K_{oc}s themselves show greater variability, the average calculated K_{oc} values are similar to those estimated during the RI/FS as reported in Tables 3-6 and 3-9 (two-phase water column estimates) of the USEPA's Data Evaluation and Interpretation Report (DEIR; USEPA, 1997).

- A comparison of the K_{oc}s for Schuylerville and Thompson Island (Figure I-2-3) showed similar and consistent partitioning behavior between the two stations. Some of the overall variability observed may be seasonally related and not random in nature.

Based on the observations and correlations presented, it was recommended that there was no longer a need to collect additional dissolved phase/particulate phase partitioning data. Sampling was discontinued in 2005. The partitioning coefficients estimated during this study were be used to understand the dynamics of the near-field release mechanism during dredging.

2.3.3 Comparison of Lock 1 and Waterford Sampling Stations TPCB Results

Weekly samples were collected and analyzed for PCBs from June 2005 through September 2005 at Lock 1 and Waterford, resulting in 42 paired samples – 33 pairs sampled on the same day, and 9 pairs where Lock 1 was sampled the day before sampling at Waterford. With one outlier excluded, regression analysis showed a strong correlation between the stations (Figure I-2-4; adj-$R^2 = 0.92$). This strength of regression is unaffected if the nine pairs of samples that were not taken on the same day were excluded. Further statistical tests of the regression coefficients indicated that the calculated slope is not different from 1 and that the estimated intercept is not statistically different from zero at a 5 percent level of significance. Therefore, water column TPCB concentrations at the Waterford station are representative of TPCBs above the Halfmoon water intake. Given this result, sampling at Lock 1 was discontinued in 2005.

2.3.4 Paired Measurement Comparison of PCB Concentrations at Historical and BMP Stations at Thompson Island and Schuylerville

One of the DQOs of the BMP was to assess whether the data from the historical stations at Thompson Island and Schuylerville could be compared with the current BMP data. Water samples were collected from the historical sampling locations at Thompson Island Dam (TID-PRW2) and Schuylerville (Rt. 29 Bridge) using techniques consistent with the historical GE sampling program (depth-integrated composite using a Kemmerer Bottle sampler). Samples were collected monthly concurrent with BMP transect sampling and analyzed for PCB. A paired t-test was used to compare the paired data sets to test if there were systematic biases between the historical sites and the current BMP locations. The paired t-test is a commonly used method for evaluating matched pairs of data, when the paired differences follow a normal distribution.

Figure I-2-5a and Figure I-2-5b show scatter plots of the paired data for Thompson Island and Schuylerville, respectively along with the one to one line. Notice that for Thompson Island, the majority of the data lie on one side of the one to one line, an indication of bias. Formal statistical test confirms that the TPCB concentrations are significantly different between the historical and current BMP stations at Thompson Island at the 5 percent level of significance. There was no statistical significant difference at Schuylerville. Therefore, historical TPCB data which was collected using historical sampling methods at Thompson Island couldn't be combined with current BMP data, whereas at Schuylerville the historical data could be used along with current BMP data to determine changes in the water column over time.

2.3.5 Temporal Patterns in Baseline Concentrations of TPCB, Tri+ PCB, TSS, POC and DOC at far-field stations

The routine water monitoring at the far field stations involved the collection and analysis of water samples for congener-specific PCBs by the Modified Green Bay Method (mGBM), TSS using EPA Method 160.2, Dissolved Organic Carbon (DOC) using NEA Method NE128_03, and for Particulate Organic Carbon (POC) using Northeast Analytical, Inc. (NEA) Method NE128_03. Figure I-2-6 presents overall average TPCB, Tri+ PCB and TSS for the far field stations. Summary statistics for these measured constituents on a monthly basis are given in Table I-2-5 and column plots showing the mean and standard deviation for each month for TPCB, Tri+ PCB and TSS are given in Figures I-2-7 to I-2-15. For all the routine water sampling stations, complete temporal profiles of TPCB, Tri+ PCB, TSS, POC, DOC and flows are presented in Appendix I-A-1. A correlation matrix detailing the relationship among the measured constituents for the various stations is summarized in Table I-2-6.

Overall, the BMP data indicated the following:

- Concentrations of TPCB and Tri+ PCB could not be explained using the relationships of concentrations of TSS, DOC and POC at all stations. In most cases the relationships were insignificant (Table I-2-6).

- Concentrations of TPCB and Tri+ PCBs are significantly higher and more variable at Thompson Island, Schuylerville, Stillwater and Waterford, compared to observations upstream of the Thompson Island Pool (Figure I-2-6). The combined impacts of current loads and historical releases to the Lower Hudson River can also be seen since concentrations in the water column remain higher even at Albany and Poughkeepsie, relative to the inputs from the Mohawk River. The consistency of values at these stations and their lack of correspondence to Upper Hudson variations suggest they are primarily governed by resuspension and exchange with local sediment inventories of PCBs and not Upper Hudson loads.

- Background TPCB concentrations upstream of GE's facilities measured at Bakers Falls range from 0.01 to 6.9 ng/L, with an overall average of 1.22 ng/L. TPCB concentrations at Bakers Falls show some seasonal differences with higher TPCBs concentrations from June to October relative to the other months. Tri+ PCB concentrations at Bakers Falls, which average about 0.21 ng/L, are relatively consistent, showing no monthly patterns. The other measured constituents including TSS (overall average of 1.87 mg/L), DOC (overall average of 4.74 mg/L) and POC (overall average of 0.29 mg/L) also do not show any significant temporal variation in concentration.

- A small but statistically significant gain in TPCB concentrations occur between Bakers Falls and Rogers Island on the order of 2 ng/L. TPCB concentrations at Rogers Island range from 0.8 to 28 ng/L, with values higher in the summer months and with a temporal pattern similar to that observed at the downstream stations. Concentrations of Tri+ PCB at Rogers Island, which average approximately 2 ng/L, are highly variable (ranging from 0.07 ng/L to 27 ng/L) with slight monthly differences in concentration. Concentrations of TSS (overall average 2 mg/L), DOC (overall average of 4.8 mg/L) and POC (overall average of 0.28 mg/L) do not show any significant temporal variation in concentration.

- Between 2004 to 2008 comparable concentrations of TPCB were observed at Thompson Island Dam (range = 5 to 143 ng/L, overall average = 38 ng/L), Schuylerville (range = 0.8 to 123 ng/L, overall average = 36 ng/L), Stillwater (range = 11 to 109 ng/L, overall average = 40 ng/L) and Waterford (range = 2 to 265 ng/L, overall average = 30 ng/L). TPCBs at these stations were relatively higher in June and July. Average Tri+ PCBs concentrations slightly increase downriver as water moves from Thompson Island to Waterford.

- There are no significant temporal variations in TPCB concentrations at Mohawk River at Cohoes (range 0.4 to 26 ng/L, overall average = 5 ng/L) and in the Lower Hudson River at Albany (range = 8 to 44 ng/L, overall average = 21 ng/L) and Poughkeepsie (range = 9 to 58 ng/L, overall average = 20 ng/L). Note that the number of samples collected at these stations is significantly lower than that collected at the Upper Hudson River stations.

- Concentrations of TSS were relatively higher at Waterford and the down river stations. Overall, mean TSS concentrations at Waterford and Mohawk were more than nine times values observed upriver. This indicates that significant solids contributions occur between Schuylerville and Waterford, which could be the result of contributions from the Hoosic and Batten Kill Rivers.

- Concentrations of DOC were similar (averaging approximately 4-5 mg/L) at each of the monitoring stations. Mean POC concentrations show higher values at Waterford relative to upriver stations, consistent with TSS observations (Table I-2-5).

2.4 Establishment of Mean and UCL TPCB and Tri+ PCB Concentrations for assessing dredge related impacts at TID, Lock 5 and Waterford Far-field Stations

To discern the contributions of PCBs originating from the remedial operations there is a need to establish the baseline concentrations and loads as well as the inherent variability in them. The Resuspension Performance Standard contains two load-based standards that are expressed as net loads, including: the far-field net daily load for a seven day running average, and the far-field net cumulative load for the season. The far-field stations for application of these standards include: Thompson Island, Lock 5/Schuylerville, and Waterford. Note that the near-field and far-field pilot study report (GE, 2009c) established that the water column PCB concentrations at the Schuylerville BMP station and the Lock 5 automated station were comparable when both stations were sampled using the manual BMP methods. Therefore, the BMP station at Schuylerville was replaced with the automated station at Lock 5 during Phase 1 dredging. Because the water column concentrations are comparable at Schuylerville and Lock 5, the BMP data collected at Schuylerville were assumed to represent baseline conditions at the Lock 5 automated station.

Equations 4-1 (Resuspension Standard, p. 87) and 4-6 (Resuspension Standard, p. 96) provide the basis for calculating the seven day average load and the cumulative loads. To estimate the seven day average daily load, Equation 4-1 requires an estimate of the 95 percent upper confidence limit of the arithmetic mean of the baseline concentration. In the case of the cumulative load, Equation 4-6 requires an estimate of the arithmetic mean of the baseline concentration.

Estimating the baseline load involves using both flow rates and concentrations, both of which vary with time. Detailed statistical analyses were used to understand the factors controlling the variability of TPCB and Tri+ PCB concentrations in the BMP data at Thompson Island, Schuylerville and Waterford to establish the baseline concentrations during the period from May to November, the active dredging season (see Appendix I-A-2 for details). The variability in flows on a seasonal and annual basis was also investigated. The results can be summarized as follows:

<u>Variability in PCB Concentrations</u>

- The significance of monthly differences between TPCB and Tri+ PCB concentrations was tested using the non-parametric Kruskal-Wallis1 test to determine if each of the months has the same median or whether at least one median is different. The results indicate that there is a statistically significant difference (p-value < 0.05) in the distributions and medians among the various months for both TPCB and Tri+ PCBs at the far-field stations. The importance of the monthly difference in PCB concentrations at these stations was also identified as part of the analysis of historical water column PCB data summarized in Appendix A of the Resuspension Performance Standard. Therefore, the determination of baseline concentrations must take into consideration monthly variability.

- On an annual basis, except for Tri+ PCBs at Waterford, there are no significant differences in median annual TPCB and Tri+ PCB concentrations for the baseline period at individual monitoring stations based on Kruskal-Wallis test results. Therefore, in general the median concentrations are comparable from one year to the next at a given station (*i.e.*, no long term change in the average annual median for the period 2004 to 2008).

- Simple regression analysis of TPCB and Tri+ PCB versus flows at each far field station resulted in weak relationships but with slopes that were statistically significant (p <0.05). The variable flow could only explain small percentage of the variability in TPCB concentration including: 9 percent at Thompson Island, 7 percent at Schuylerville and 16 percent at Waterford. For Tri PCB, flow could only explain 2 percent of the variability at Thompson Island, 1 percent at Schuylerville and 31 percent at Waterford. Therefore flow cannot explain a significant portion of the variability inherent in PCB concentrations at the far field stations (see Appendix I-A-2 for details).

- A second set of regression analysis, multiple regression analysis, was performed by relating TPCB and Tri+ PCB with flows and the various months included as qualitative predictor

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[1] The Kruskal-Wallis test is a nonparametric (distribution free) method of testing the hypothesis that several populations have the same continuous distribution versus the alternative that measurements tend to be higher in one or more of the populations.

variables. This analysis was conducted by incorporating the months as indicator variables that take on values of 0 or 1 (see Appendix I-A-2). The inclusion of months as additional predictor variables significantly increased the amount of variability explained by the multiple variable regressions. For example, the multiple regressions explained 35 percent of the TPCB variance at Thompson Island, 37 percent at Schuylerville, and 28 percent at Waterford. For Tri+ PCB the multiple regressions explained 22 percent at Thompson Island, 47 percent at Schuylerville, and 45 percent at Waterford. While the overall variances explained by the multiple regressions are not enough to rely on the regression models, they further underscore the importance of monthly variability in the BMP far-field PCB concentrations. Note that some of the monthly indicators are not significant in the multiple regressions, indicating that there is no relationship between flow and PCB concentrations during these months.

Variability in Fort Edward Flow

- Kruskal-Wallis test performed on the flows at Fort Edward indicated significant seasonal differences during each year of the BMP and the Phase 1 dredging year of 2009. The intra-annual patterns differ from year to year.

- The annual distributions of flows during each year of the BMP are also significantly different, with 2006 being the highest flow year during the BMP study period, as well as the highest flow period on record. Note that the year 2009, when Phase 1 dredging occurred, had a statistically different distribution relative to the other BMP years; 2009 was the second highest flow period during the BMP study period, as well as the second highest on record.

Estimating Baseline Concentrations for 2009 Phase 1 Dredging Season

The above statistical findings indicate that both parameters used to calculate load, concentration and flows, vary on a monthly basis. In the case of flows, annual differences are also significant. Since flows are measured continuously and are available real-time from the USGS during remediation, the question then becomes one of establishing the appropriate baseline concentration of TPCB and Tri+ PCB to be used for load calculation. Because, the regression relationships obtained using both flows and months are significant but weak, the following method which takes both the monthly variability and the weak correlation with flow into consideration was used to determine baseline mean and UCL concentrations for evaluating dredging impact during Phase 1:

- The TPCB, Tri+ PCB and flow data during the BMP period from 2004 to 2008 (only May to November considered each year) were divided into months. For each month all reported data were used except for three high concentrations for Waterford observed in June 2006 when flows for the Lock 1 USGS gauge was greater and 25,000 cfs. During this week in June 2006 about half of the TPCB load at Waterford (for the May – November period) was transported downriver, indicating that high flow events are significant in load determination. The exclusion of these high flow concentrations provides a conservative biased low estimate of the baseline concentration for Waterford.

- To account for the possible weak but statistically significant correlation between PCB concentrations and flow, the data were stratified into three flow categories and baseline concentrations were estimated for these categories. These flow categories include: flows less than 5000 cfs at Fort Edward, flows between 5,000 cfs and 10,000 at Fort Edward, and flows > 10,000 cfs at Ft Edward. The 5,000 cfs and 10,000 cfs boundaries seemed to be a logical break suggested by the data.

Tables I-2-8 and I-2-10 present the mean TPCB and Tri+ PCB baseline concentrations. Tables I-2-7 and I-2-9 present the UCL of the mean for TPCB and Tri PCB baseline concentrations. The mean concentrations were applied as the baseline concentrations in Equation 4-6 of the Resuspension Standard to determine seasonal baseline loads for the Phase 1 dredging season. The results of UCL of the mean were applied as the baseline concentrations in Equation 4-1 of the Resuspension Standard to determine the seven day average loads.

2.5 Baseline Seasonal Loads (May to November) for Thompson Island, Lock 5/Schuylerville and Waterford

The BMP TPCB and Tri+ PCB concentration and flow data were used to determine the observed loads between May 15 and November 30 for each BMP year (2004-2008) (Table I-2-11). The seasonal baseline load for Phase 1 dredging in 2009 was estimated using 2009 flows and mean concentrations from Table I-2-8 and Table I-2-10 consistent with the Resuspension Standard. The seasonal baseline loads indicate the following:

- For each station, the highest load occurred in 2006 which was the highest flow year in record. The difference between the 2006 loads and loads for other BMP years is much greater at Waterford than the other stations. Because the sampling program specifically targeted storm event sampling at Waterford, the loads estimated at this station are more accurate and representative of flow conditions during the BMP sampling period. The lack of high flow sampling at Thomson Island and Schuylerville likely resulted in underestimating the impact of the 2006 high flow events.

- An important finding is that the loads for TPCB and Tri+ PCB increased downstream. Although average PCB concentrations are comparable at the three stations (Section 2.4), the loads increase observed are mainly due to the additional watershed gain in river flows from TI to Waterford. Therefore, the total volume of water in the river plays an important role in estimating potential baseline loads. The total water volume for Fort Edward station in 2006 was almost 1,000 billion gallons, and at Lock 1 the value was about 1,500 billion gallons.

- For 2009, the year of Phase 1 dredging, loads were estimated based on the fact that concentrations at the different stations are similar during the BMP years, and therefore average concentrations pre-2009 were paired with observed flows to determine load. This is consistent with Equation 4-6 of the Resuspension Standard at Waterford in particular, the seasonal TPCB load in 2009 are higher than all BMP years except 2006. This was expected because 2009 was the third wettest year on record, equivalent to one in eleven year event (Figure I-2-16).

In estimating baseline loads for application during Phase 1 dredging in 2009, GE (2010) in its draft Phase 1 evaluation report incorrectly applied the use of the 95% UCL for calculation of the seasonal net load in its comparison of various methods. Equations 4-1 (Resuspension Standard, p. 87) and 4-6 (Resuspension Standard, p. 96) provide the basis for calculating the seven day average load and the seasonal cumulative net loads, respectively. These are the only approved methods for calculating the load and were peer reviewed as part of the development of the Resuspension Standard and do not include the use of the 95% UCL as GE applied it.

To estimate the seven day average daily load, Equation 4-1 requires an estimate of the 95 percent upper confidence limit (UCL) of the arithmetic mean of the baseline concentration. The UCL method is entirely appropriate for calculating the 7 day averages to assist in controlling the dredging operations. Its use ensures that any releases are dredging related, and no unnecessary shutdowns occur, while still being protective of the water supplies.

In the case of the seasonal cumulative net load, Equation 4-6 requires an estimate of the arithmetic mean of the baseline concentration. The seasonal cumulative load as calculated with this equation yields a conservative estimate of the net load to the Lower Hudson (i.e., crossing Waterford) (see Section 3.3).

GE used two methods to estimate baseline loads. The first was a rating curve correlation method of monthly loads versus flows. Because the correlation between concentrations and flow is very weak, the rating curve is of limited value as it is simply a correlation between flow and flow. Shivers and Moglen (2008) found that the use of this load based regression approach exhibits spurious correlation, and called for the use of sound statistical methods.

The second method GE used to estimate seasonal loads is its so called "subtraction" method for calculation of load to the Lower Hudson. The approach by GE has several major flaws including, but not limited to, exclusion of complete data sets in setting baseline values, manipulation of data (e.g., from one month to another), failure to acknowledge the increase in baseline loading from Thompson Island to Waterford, and disregarding the objectives for which the baseline data were collected. For example, GE only considered baseline data for 2005 and two low flow years 2007 and 2008 and as a result, the baseline loads are underestimated and the corresponding net loads caused by resuspension to the Lower Hudson are over-estimated by GE's method. Since 2009 had the third highest flow on record, excluding 2004 and 2006 data from the analysis results in an underestimation of the baseline loads, and subsequently in over-estimating the net loads to the Lower Hudson during dredging. Furthermore, GE validated its approach by the reduction in gross load during dredging from Thompson Island to Waterford as being applicable to baseline conditions. This assumption is contrary to baseline observation that load increases from Thompson Island to Waterford during the BMP period. The baseline loads at Waterford are always higher than those at Thompson Island and appear to be related to flow (i.e., the higher the flow, the higher the baseline load at Waterford). The exclusion of this difference in the baseline load results in an inaccurate and higher net load at Waterford.

2.6 Annual Baseline Load to the Lower Hudson River

The PCB loads at Waterford under baseline conditions provide a basis to assess the effectiveness of the remedy in reducing PCB load to the Lower Hudson River. The Resuspension Performance Standard , Page 4 defines the net export of PCBs to the Lower Hudson as the PCB resuspension export rate at the Waterford-Lock 1 Station, *i.e.,* the load of PCBs at this location that is attributable to dredging-related activities. The Waterford-Lock 1 station was selected because it is downstream of the dredging target areas identified in the Feasibility Study or dredge area delineation during design but upstream of the Mohawk River, which was shown to be a minor but measureable source of PCBs to the Lower Hudson River. The loads estimated in this section were used to assess the need for load changes in Section 3.3.5, based on comparison to HUDTOX model forecasts.

There are several methods available to calculate loads, and empirical studies have been utilized to compare the various mass-load estimators. One of the most used estimators that consistently provide low bias (Dolan et al, 1981; Preston et al., 1992) when ample flow data exists with only limited concentration data is the Beale's Ratio Estimator. This corresponds to Method 3 of the six loading calculation methods provided in the USACE program FLUX (Walker, 1985). The USACE FLUX program was used to determine the annual loads at Waterford for the years 2005 to 2008, and the results for Method 3 were selected for each year. Note that for 2004, sampling started in June, and therefore, an annual load was not estimated.

Table I-2-11 presents the annual cumulative water volume past Waterford, and the annual loads of TPCB and Tri+ PCB along with the errors expressed as coefficient of variation.

2.7 Summary of Baseline Fish Tissue Result

Baseline fish tissue analysis is provided in Appendix I-C.

3 – ASSESSMENT OF DREDGING RESUSPENSION PERFORMANCE AND ITS IMPACT

3.1 Overview of Dredging Resuspension Evaluation

This Section focuses on evaluating the performance of the Phase 1 dredging program with respect to compliance with the Resuspension Standard. This phase of the dredging was designed to remove approximately 265,000 cy of contaminated sediment from 18 certification units (CUs) located in the following two areas: i) The northern portion of the Thompson Island Pool from the northern end of Rogers Island to the southern end of Rogers Island on the east side of the island and to approximately River Mile (RM) 194.1 on the west side of the island and ii) the area of the river in the vicinity of Griffin Island, between RM 190.4 and RM 189.9. Sediment dredging was conducted primarily in 10 of the 18 CUs from May 15 – October 27, 2009, using environmental clamshell dredging equipment. The dredged sediments were transported by barge to a land-based sediment processing facility. After contaminated sediment removal, designated dredge areas were backfilled or capped in accordance with the residuals standard. A summary of the activities during Phase 1 dredging are as follows:

- In-river activities began on April 13, 2009 with tree trimming along the shoreline to provide overhead clearance for dredges within the near-shore areas.
- A rock dike was constructed at the northern end of the east channel of Rogers Island in early May to reduce flows to that channel during dredging operations.
- Targeted river debris removal activities began on May 15, 2009, and were largely complete by the middle of June 2009.
- Inventory dredging began on May 15, 2009, in the west channel of Rogers Island in CU-9.
- Dredging was slowed during May and early June 2009 due to elevated river flows that restricted barge and tug operations in the west channel of Rogers Island.
- On June 1, 2009, dredging began in the east channel of Rogers Island in CU-1 and CU-2.
- On June 25, 2009, dredging began in the East Griffin Island Area (EGIA) in CU-17.
- Sheet pile installation in CU-18 began on June 1, 2009 and continued through July 11, 2009. Dredging inside the sheet piled area began on July 22, 2009. Removal of the sheet pile began on August 20, 2009, and was completed on October 2, 2009.
- Sheens on the surface of the river were noted during debris removal activities in CU-3 on May 27, 2009. Sheens attributed to debris removal and dredging activities were a common occurrence in the east channel at Rogers Island and in the EGIA. Analysis of sheen samples indicated that the sheens contained elevated PCB concentrations.

- Dredging operations were suspended for several days in early August 2009 due to measured water column TPCB concentrations above the federal MCL of 500 ng/L at the Thompson Island far-field station. Dredging operations were incrementally brought back online in the following week. In September 2009, after discussion with EPA, dredging was temporarily discontinued in CU-4 and CU-18 due to TPCB concentrations above 500 ng/L in the water column,

- As reported in GE's Data compilation report (GE, 2009d), approximately 3,000, 36,000, 73,000, 65,000, and 66,000 cy of sediment were dredged from the river in May, June, July, August, and September 2009, respectively. These totals include inventory, residual, and navigational dredging volumes removed primarily from CUs 1-9, 17 and 18.

- On September 14 and 15, 2009 backfill placement demonstrations began in CUs 17 and 5. By September 21, 2009, backfilling began in these two CUs.

- Dredging and backfilling were completed in the first CU (CU-5) on September 28, 2009.

- Dredging was suspended for the season on October 27, 2009.

- The rock dike in the East Rogers Island was removed in stages between November 21 and December 3, 2009.

- On the evening of November 17, 2009 boat traffic significantly increased in-and-around Thompson Island Dam due to recovery efforts following a boating accident at the dam.

USGS average daily flows observed during the Phase 1 dredging period averaged above 5,000 cfs, as monitored at Ft Edward (Figure I-3-1a). The daily flow at Ft Edward exceeded the 10,000 cfs on May 18, 2009 and values remained above 7000 cfs after the active dredging ended. At the downstream Lock 1 Gauge, flows were on average 60 percent higher than at Ft Edward, consistent with the drainage area increase between the two stations. However during the peak flow events, on August 1, 2009 and October 25, 2009, the flows at Lock 1 were over three times higher than values recorded at Ft Edward (Figure I-3-1a). Review of the historical flow record at Fort Edward indicates that 2009 correspond to the third wettest year on record (Figure I-3-1b). Under normal flow conditions, flows through the East and West Channels of Rogers Island occur roughly in the proportion of one-third to two-third, based on USGS and other studies. Before Phase 1 dredging started, a rock dyke which permitted only 4 percent of the flow to go through was constructed as a resuspension control measure in the East Channel. Thus the rock dike resulted in a 50 percent increase in flow through the West Channel which raised its average flow to the equivalent of 8,600 cfs flow, higher on average than any year on record (Figure I-3-1b).

During Phase 1 dredging, extensive water column, sediment, fish and productivity data were collected to assess the project's achievement of the project standards. As described in Section 1 of this report, the Resuspension Performance Standard specifies a routine monitoring program with three action levels: Evaluation, Control, and Standard Levels. These action levels apply to PCB concentrations and/or total suspended solids (TSS) in surface water at either near-field stations (located within 300 meters [m] of the dredging activities) or far-field stations (located more than 1 mile downstream of dredging activities), as well as PCB loadings at the far-field stations. These action levels were used to trigger certain contingency actions during dredging activities. This Section presents the following:

- Evaluation of dredging performance through near-field monitoring
- Evaluation of dredging performance through far-field monitoring

3.2 Evaluation of Dredging Performance in the Near-field Stations

3.2.1 Phase 1 Near-field Monitoring Setup

The near-field monitoring program was designed to evaluate on a real-time basis whether dredging activities have caused near-field TSS to be elevated to an extent indicative of elevated rates of PCB export from dredging activities. The near-field monitoring area encompassed the immediate vicinity of remedial operations, nominally extending from 100 feet upstream to 1 mile downstream. The monitoring consisted of data collection from floating buoys deployed upstream and downstream of dredging operations and from boats which traversed the river along transects located upstream, adjacent to, and downstream of dredging operations. The buoys were equipped with automated samplers, multi-parameter water quality sondes, a datalogging system, and near-real-time data transmission capabilities.

The monitoring buoys were deployed both upstream and downstream of each dredging operation (or group of operations when located in close proximity to one another) at a station located approximately 100 m upstream of the dredging operation and a station located approximately 300 m downstream of the dredging operation. In addition, although the Resuspension Standard originally planned for each dredge operation to be monitored in the near-field; multiple dredging platforms were monitored as a single operation because of the relatively large number of project related vessels located in close proximity to one another. The latter was accomplished by dividing the river into geographic operational areas (Figure I-3-2) with all work occurring in a particular area assigned to that operation. The automated samplers on the monitoring buoys were programmed to obtain four 6-hour composite samples per day from mid-depth in the water column for TSS analysis. In addition to automated buoys, monitoring was conducted by boat twice per day at transects located 100 m upstream of each dredging operation (or group of operations when located in close proximity to one another), 100 and 300 m downstream of each dredging operation, and approximately 10 m adjacent to each dredging operation parallel to flow.

Overall, the geographic locations and the monitoring set up in the near-field included:

- The East Griffin Island area, monitored as part of a special study, consisted of six buoys deployed around CU-17 and CU-18, one approximately 100 m upstream, one side channel buoy placed in-between the CUs and the navigational channel, one buoy approximately 100 m downstream of CU-18, and two buoys to the east of the navigational channel approximately 300 m downstream of the EGIA area. One additional buoy was placed inside the silt barrier containment area. Boat-run transects were not performed in the EGIA. The results from this special study will be discussed in Section 4.

- In the East Rogers Island a rock dike isolated the channel from the main river and a different monitoring scheme was employed. One buoy was located within the contained area in the vicinity of the Washington County Sewer District wastewater treatment plant (WWTP) discharge. Two other buoys, called downstream east and west, were deployed approximately 30 m downstream of the silt curtain located at the southern end of the east channel (Figure I-3-2). Additionally, a single boat-run transect was run across the east channel at Rogers Island, downstream of the silt curtain in the vicinity of the two buoys also deployed in that area. Note that a Rogers Island Background Buoy was located upstream of remedial activity to provide background data upstream of all remedial activities.

- The West Channel of Rogers Island consisted of 6 sub-monitoring setups spanning the area from CU-5 to part of CU-11. The typical monitoring setup in this area consisted of: a 100 m upstream buoy and boat-run transect, a 300 m downstream buoy and boat-run transect, and a 10 m side channel boat-run transect.

- The Lock 7 area consisted of 4 sub-monitoring setups. The typical monitoring setup in this area was similar to the setup in the West Channel of Rogers Island.

3.2.2 Near-field Monitoring Results

The near-field Evaluation and Control Levels criteria specify a threshold of TSS increases over the upstream observations of 100 mg/L and 700 mg/L, respectively. Time series plots of turbidity and TSS for each monitoring buoy/transect at all the locations are presented in Appendix I-B. In each turbidity time series plot, turbidities of approximately 85 NTUs and 593NTUs, which correspond to the TSS criteria of 100 mg/L and 700 mg/L, were depicted. The turbidity estimates at these TSS threshold levels were derived from GE's relationship between turbidity and TSS (where TSS = 1.18 x Turbidity - 0.25), developed as part of the far-field near-field pilot programs. When higher TSS concentrations were observed at any near-field monitoring location the TSS threshold of 100 mg/L was indicated in the plots. For the transect results, scatter plots of grab TSS versus corresponding turbidity were constructed to assess the goodness of fit of turbidity as a TSS surrogate. Summary statistics of the TSS data for each monitoring buoy and transect deployed at each geographic location are presented in Table I-3-1. Figure I-3-3 presents the mean and standard deviation of TSS results for each monitoring sub-unit starting from upstream to downstream. Furthermore, paired statistical comparisons were performed for each combination of upstream and downstream buoy TSS data, to check for significant systematic differences that could be the result of dredge-related activities (Table I-3-2).

The major conclusions from the near-field results are that TSS was not a good predictor for PCB release and transport, and that average TSS concentrations in the near field were well below the Evaluation criteria of 100 mg/L at 300m and 700 mg/l at 100 m downstream of the dredging operations, respectively, with a few exceptions. The low TSS concentrations generally observed in the downstream near-field buoys and transects, relative to the standard requirement indicate that there was no significant transport of solids during dredging beyond the immediate vicinity of the dredging operation. With the exception of the buoys in the vicinity of Lock 7 area, TSS concentrations in the downstream buoys were generally higher than corresponding values in upstream buoys for most operations. The median differences in concentrations between the TSS concentrations in the upstream buoys and the TSS concentration in the downstream buoys were less than 5 mg/L in all cases (Table I-3-2). Paired statistical tests indicated this small difference is significant. As expected higher TSS concentrations were observed within containment areas compared to values outside of these containment areas, but even the values within the containment area are well below the TSS concentration criteria. In West Rogers Island, TSS concentrations in downstream buoys, relative to their upstream counterpart, tended to be more variable after late September, probably reflecting the effect of backfilling of CUs (see Appendix I-B). Furthermore, turbidity was not a reliable surrogate for TSS and the surrogate relationship develop during bench scale studies performed poorly because of generally low TSS/Turbidity observations. Other observations from the near-field data are as follows:

- TSS Concentrations at the Rogers Island Area Background buoy station which represent ambient concentrations upstream of dredging (average = 1.53; range = 0.49-14.6 mg/L) were comparable to the Baseline Monitoring Program (BMP) concentrations observed at Rogers Island (average = 2.05 mg/L; range = 0.45 – 18.9).
- The relatively higher concentrations of TSS within containment areas compared to values outside the containment areas indicated that the containments were capable of limiting the transport of higher TSS downstream of the dredging operations.
- There were some differences between TSS concentrations observed from the buoys TSS concentrations obtained via boat transects at locations were both buoys and transect grabs were collected. These differences highlight the difficulty of making inference from snapshot samples collected from transects in understanding PCB dynamics during dredging.
- Throughout dredging, TSS concentrations observed at the 10 m side channel boat transect and 100 m downstream buoy and transects were significantly below the near-field criterion

of 700 mg/L. The TSS in the side channel transects failed to capture any impacts that boat or other related movement activities created during dredging.

- Time series plots of turbidity show peaks of higher turbidity values that exceeded 85 NTUs and sometimes 593 NTUs but without corresponding peaks in TSS measurements. In some cases these peaks in turbidity are isolated and occur within the 15 minute time scale of the measurement. The lack of a response in TSS concentrations indicates either an errant reading, or a short-pulse of suspended matter that was transported downstream before the next aliquot of water was taken by the automated sampler at the buoys.

- There are also periods during which turbidity remained high during the 6-hour averaging period, but the corresponding TSS observation was not reflective of a plume of suspended solids being transported downstream. For example at EGIA 300m downstream buoy west, on August 21, 2009, turbidity averages 100 NTUs and 65 NTUs between 0:00- and 6:00 and 6:00-12:00, respectively. The corresponding TSS recorded during these periods was 4.41 and 1.62, respectively, suggesting that the turbidity readings were not truly reflective of elevated TSS on a consistent basis.

- The inconsistencies between elevated turbidity and the lack of response in TSS resulted in poor agreement between turbidity and TSS observations. These poor agreements suggest that turbidity cannot be relied upon to infer solids transport during dredging as it could have provided several false positives about the impact of dredging.

3.3 Evaluation of Far-Field Concentrations of PCBs and TSS and PCB Loads

This section presents the result of the far-field monitoring program. It is divided as follows:

- Phase 1 Far-field Monitoring Setup – A brief description of the actual Phase 1 monitoring setup, highlighting any changes to the specifications in the RAM QAPP

- The far-field water column concentration – A description of the time series of TPCB (TPCB), Tri+ PCB, TSS, particulate organic carbon (POC) and dissolved organic carbon (DOC) at the far-field stations. At Thompson Island, Lock 5 and Waterford stations, TPCB concentrations are compared to: the Resuspension Standard of 500 ng/L. The seven-day running average concentrations were compared to the Control Level of 350 ng/L, and the net TSS concentrations were compared to the Control Level of 24 mg/L.

- Far-field Net TPCB and Tri+ PCB Daily Average Load – A description of time series of the seven-day average net TPCB and Tri+ loads, is presented and the results compared to the Evaluation Criteria of 541 g/day and 180 g/day for TPCB and Tri+ PCB and Control Level Criteria of 1,080 g/day and 361 g/day for TPCB and Tri+ PCB.

- Far-field TPCB Seasonal load – Estimated cumulative loads during the Phase 1 dredging season from May 15th to November 27th are presented and compared to the Control Level Criteria of 117 kg/yr for TPCB and 39 kg/yr for Tri+ PCB. In addition, the cumulative loads are compared to 1 percent of the actual mass removed for TPCB (200 kg/yr) and Tri + PCB (55 kg/yr) during Phase 1 dredging.
- Impact of Loads to the Lower Hudson River – A discussion of the restrictive nature of the cumulative load limits based on the current information.

3.3.1 Phase 1 Far-field Monitoring Setup

The far-field monitoring area is that portion of the Hudson River that is greater than 1 mile downstream from active dredging operations. The far-field monitoring program was designed to: advice public water suppliers when water column concentrations are expected to approach or exceed the federal maximum contaminant levels (MCL), evaluate the achievement of the Total and Tri+ PCB load components of the Resuspension Standard, and determine background TPCB levels entering River Section 1 from upstream.

The far-field monitoring included manual collection and automated collection of samples from a number of stations along the river. Sampling in the far-field was conducted in accordance with the procedure detailed in Phase 1 RAM QAPP (GE, 2009a) and summarized in Section 1 of this report. The only modifications made to the monitoring were related to metals monitoring which is part of the Substantive Water Quality requirements.

3.3.2 Far-field Water Column Concentrations

Observed TPCB, Tri+ PCB, TSS, POC and DOC at the far-field stations are presented in Figure I-3-4 through Figure I-3-8. Concentrations of the various measured constituents at Bakers Falls during the Phase 1 dredging period are consistent with concentrations observed under baseline conditions, since this station is located upstream of the remedial activities. During the dredging period, TPCB at Bakers Falls varied within 1-2 ng/L with an average of 1.4 ng/L. A small but statistically significant gain of 2 ng/L in TPCB occurred between Bakers Falls and Rogers similar to observations during the BMP. TPCB concentrations at Rogers Island above 5 ng/L occurred on 5 occasions, but these peaks are not coincident with higher TSS concentrations at the station. Overall, the discrete manual TSS samples collected at Rogers Island lie within the TSS concentrations reported for the 6-hour average automated samples collected in the Rogers Island Background Buoy station as part of the near-field monitoring program.

At all far-field stations, concentrations of POC and DOC were consistent with BMP observations. Average DOC during dredging was just under 5 mg/L and there were no station to station differences. The lack of an increase in DOC at Thompson Island and Lock 5 stations, which are closest to the remediation, indicates that DOC cannot explain the increased dissolved phase concentrations associated with the dredging. Therefore, the hypothesis by GE (see Section 2.3.2) that DOC is a likely third phase for non-particulate bound PCBs is not supported by this observation. The release of NAPL from the sediments during dredging represented the additional phase of PCB transport to the far field stations. .

Dredging and other related operations caused elevated water column PCB concentrations at Thompson Island, Lock 5, Stillwater and Waterford significantly above baseline concentrations from the onset of dredging in mid-May. TPCB concentrations at the Thompson Island station generally ranged between 100 and 400 ng/L over much of the dredging period. The average concentration before October 27th was 200 ng/L, which is about two times higher than the average value observed from October 28th to December 5th. There were several factors that likely contributed to the release of PCBs during dredging including but not limited to: release of PCB contaminated oil sheens from within the sediment, vessel traffic, dredge bucket decanting into the river, spillage from non-closed dredge buckets, the number of bucket bites, sediment removal rates, and debris removal. The impact of debris removal was extensively documented in the EPD Field Oversight Report. Debris removal was conducted at the beginning of the Phase 1 dredging program. It commenced on May 15, 2009 and removed debris targets (Figure I-3-9) previously identified through side scan sonar and multi-beam bathymetric and sub-bottom profiling surveys and non-targeted debris (Figure I-3-10) encountered in the various CUs throughout Phase 1 dredging. Primary removal was successful for large debris (*e.g.,* tree trunks). However, subsequent debris passes primarily for smaller targets were not productive but created significant resuspension.

The federal maximum contaminant level (MCL) of 500 ng/L was exceeded three times during the course of the project at Thompson Island, which resulted in the suspension or alteration of dredging operations. [Note that GE in its Draft Phase 1 Evaluation Report applied a correction factor (see Section 1.10) to the PCB concentrations and reported ten exceedances of the federal MCL. EPA has not approved the use of the correction factor]. The three exceedances of the federal MCL occurred on August 6 – 8, September 10, and October 13. Beginning July 25th, the seven day flow weighted concentrations started to increase towards the Control Level of 350 ng/L. The increase continued until the Control Level was reached on August 1 and further increases were observed until the federal water standard was exceeded. The action level of 350 ng/L, which is specified as a seven-day flow weighted average, provided the intended guidance during this period as the continuing increase of the average concentrations pointed towards the forthcoming exceedance. The action levels were developed to help identify potential and impending problems and to guide appropriate responses, as a means to avoid an exceedance of the Resuspension Standard. Following the confirmation of the August 6 through 8 exceedance of the federal MCL, EPA directed GE to temporarily halt dredging operations and initiate an engineering evaluation to identify the reasons for the exceedance of the Resuspension Standard and to use a phased approach when restarting the dredging. This engineering evaluation indicated the presence of significant dissolved phase PCBs in the water column.

The exceedances of the Resuspension Standard on September 10, 2009 and October 13, 2009 were not confirmed by subsequent replicate samples. It is likely that these concentrations, while high, were more uncertain, since during the project significant variability was observed in some of the duplicate measurements. This variability in part was likely due to the non-homogenous nature of the oil sheen reported during dredging. Samples of the oil sheens analyzed (see Section 4.4), showed significantly higher PCBs, but replicate results varied by more than an order of magnitude in some cases. The large disparities in the duplicate samples are indicative of the difficulty in capturing the sheens in the sample containers. The oil phase was not separated from the aqueous phase during the oil sheen study making it difficult to determine the fingerprint of the PCB in the pure oil sheen product as well as the nature of the oil sheen itself. The PCB concentrations in surface oil sheen samples were significantly higher than in corresponding water samples collected at mid depth from the water column from the same location.

Another factor that likely had a significant effect on TPCB concentrations in the Thompson Island pool was vessel traffic. While there were no specific evaluations of the impact of vessel traffic on TPCB concentrations there were two incidences that support this premise. First, between May 16 to 19, 2009, GE reported that a large hopper barge floated off one of its spuds when water levels in the river rose and became grounded between CU-9 and CU-10. Five tugs were needed to pull the barge back into deeper water and refloat it. A spike in the TPCB concentration of 326 ng/L was observed around May 18, 2009, prompting an engineering evaluation. A GE bathymetric survey identified several large scour holes (up to 5.5 feet deep, and even larger, in diameter in the river bottom following the incident). A second incident of vessel traffic impact occurred on November 17, 2009, when an unfortunate accident occurred at the Thompson Island Dam, resulting in an increase of rescue boat activity in that area and spike of TPCB of 250 ng/L in the water column. In addition, there was evidence of sediment scouring from barges which were moved near the shore and into shallow depths. Tangentially, this also indicates that boat vessel scouring may have significant impact to TPCB concentrations under normal conditions, absent of dredging. To further understand the effect of boat traffic on PCB concentrations measured in the far field, boat distance travelled was plotted against Thompson Island TPCB concentrations on Sundays when there was no dredging (Figure I-3-12). The results indicate a statistically significant correlation between boat traffic and PCB transport even when dredging was not occurring.

The concentrations of TPCB at Thompson Island showed no relationship to flow during dredging. Furthermore, the TPCB concentrations did not vary with TSS, which may be related to the influence of non-particulate phase PCB transport downstream of dredging. Tri+ PCBs at Thompson Island were on average 45 percent of the TPCB concentrations. Concentrations of TSS measured at Thompson Island, which average about 3 mg/L, were comparable to baseline conditions. The lack of a significant difference in TSS concentrations between baseline conditions and during dredging underscores the importance of the transport of non-particulate phase PCB transport downstream of dredging.

TPCB concentrations at Lock 5 (Schuylerville), Stillwater and Waterford were also elevated above baseline during dredging. At Lock 5, TPCB concentrations during the period May 15 to October 27, 2009 averaged 155 ng/L. This average decreased to 65 ng/L after dredging was halted for the season. The seven-day flow weighted average TPCB concentrations never exceeded the Control Level of 350 ng/L at Lock 5. On October 27, 2009, a measured concentration of 634 ng/L, was reported for the Lock 5 station, which exceeded the Resuspension Standard. However, the corresponding value at Thompson Island was 430 ng/L, a difference of slightly more than 200 ng/L. It is likely that this discrepancy was an analytical problem and not an actual exceedance at Lock 5. A second analysis of a sample with the same collection date and time (sample ID: WFF-LOC5-091027-UT003) was reported as 248 ng/L, which was about 2.5 times lower than the high value of 634 ng/L. The average of the two reported values at Lock 5, 445 ng/L, was close to the Thompson Island measurement. The average Tri+PCB to TPCB ratio at Lock 5 was 2.4.

TPCB concentrations at Thompson Island were generally higher than concentrations at the Lock 5 station, however the differences were relatively consistent and showed variation and magnitude with time, except during the following two periods where the difference in TPCB concentrations between the two stations was more pronounced: July 30 to August 8, 2009; and October 6 to 16, 2009. The exact reason for these differences is not known. However, the observations during these periods were as follows:

- The first period, July 30 to August 8, 2009, occurred when concentrations at TID were increasing until they exceeded the resuspension standard. The average TPCB concentration at Thompson Island during this period was 420 ng/L which was a little less than twice the observed average at Lock 5 of 230 ng/L. Flows, as measured at Fort Edward, were high during this period, averaging above 7,000 cfs. Average concentrations of TSS at Thompson Island were slightly higher, by 1.7 mg/L, however the paired differences between the two stations were not statistically significant. The comparable TSS concentrations and higher flows suggest that settling of solids between Thompson Island and Lock 5 may not have been a significant mechanism responsible for the decreasing TPCB concentrations from Thompson Island to Lock 5.

- October 6 to 16, 2009, is the second period during which TPCB concentrations at Thompson Island of approximately 330 ng/L were twice the measurements at Lock 5 (150 ng/L). During this period, the average flow was 6,500 at Ft Edward which was above the flow average of 5,800 cfs during the dredging period. TSS concentrations at Lock 5 where slightly higher than at TID by 0.7 mg/L. These conditions suggest that settling of solids again cannot explain the significant difference in TPCB concentrations.

TPCB concentrations at Waterford were lower than observations at Thompson Island and Lock 5, with averages from May 15 to October 27, 2009, of 75 ng/L. After October 27, 2009, average TPCB concentrations at Waterford decreased to 29 ng/L, consistent with baseline levels. The average TPCB to Tri+PCB ratio, which was approximately 2.7 at Waterford, and compares to the ratios observed upstream at Thompson Island and Lock 5. Concentrations of TSS averaged above 10 mg/L at Waterford, which is more than three times the average at Lock 5. Therefore the watershed area below Lock 5 was able to produce much more solids compared to the area above it. Likely mechanisms responsible for the decrease in PCBs from Lock 5 to Waterford include dilution from increased volume from the watershed and volatilization. However the lack of intermediate transects further down in the far field and the fact that only whole water samples were analyzed make a complete assessment difficult.

Downstream of the Waterford station, TPCB concentrations at Mohawk (average = 5.6 ng/L), and Poughkeepsie (average = 21 ng/L) during dredging compare to average values reported for the baseline period. However, the TPCB concentrations at the Albany station during dredging were higher than concentrations observed during the BMP. At Albany, TPCB concentrations ranged from 25 to 114 ng/L with an average of 59 ng/L, about three times higher than the BMP average of 21 ng/L (BMP range = 8 to 44 ng/L). Concentrations of Tri+ PCB at these downstream stations at Albany (12 ng/L), Mohawk (average 2 ng/L) and Poughkeepsie (average = 14.5 ng/L) were comparable to the baseline observations. The observations at Albany indicated that the TPCBs at this station were dominated largely by the lighter end PCB congeners, because the TPCB to Tri+ PCB ratios average about 5. It is unclear where the additional mono-PCB and di-PCB originated from, since this ratio is unsupported by BMP observations and observations upriver during dredging.

3.3.3 Statistical Analysis of Factors Affecting Water Column PCB Concentrations at Thompson Island During Dredging

In GE's Draft Phase 1 Evaluation Report (GE, 2010), GE was reported that water column concentrations can be predicted based only on PCB removal rate and river velocity. EPA has conducted a preliminary analysis of factors associated with water column PCB concentrations (see Appendix I-D) and has found that while water column PCB concentrations are indeed positively associated with mass of PCBs removed, a more careful analysis suggests that this relationship is due to a combination of several operational factors, some of which are readily manageable in ways that would logically be expected to reduce PCB releases associated with dredging operations. Based on EPAs recent analysis, it can be concluded that the mechanisms associated with increased water column PCB concentrations are varied and likely, many and should not be simplified to a simple proportionality to mass removed, as suggested by GE. Mass removed is a surrogate for the net effect of all of the processes involved in dredging, and therefore correlates well with water column PCB concentrations. However, this does not preclude that of individual operational variables can be managed to reduce resuspension of PCBs. EPA continues efforts along these lines to investigate factors identified in its analysis and their potential as causative agents as opposed to just surrogates. It is anticipated that these efforts will provide information necessary to develop operational management strategies.

3.3.4 Patterns of PCB Loss During Downstream Transport

The gross concentrations of PCB measured at Thompson Island, LOCK 5 and Waterford show a decline during transport through the Upper Hudson. The Total to Tri+ PCB ratios for these three far each station were calculated and compared to observations made in the near field as part of special studies (see Special Studies in Section 4). The results indicate that the composition of PCB shift to higher chlorinated congeners as the water is transported from the near field to the far field (Figure I-3-13). This observation can be explained by the higher Total PCB to Tri + PCB ratio in the near field relative to observations in the far field. A second observation about the composition of PCBs in the far field was that there was a shift to the higher chlorinated congeners under high flows (Figure I-3-14).

Patterns of PCB homologue gross load, and mass lost between Thompson Island and Lock 5, and between Lock 5 and Waterford were investigated to understand the mechanisms of PCB loss during downstream transport. To avoid impacts of time-of-travel, the analysis focused on total loads for three different periods: 1) July 5 through October 27, since PCB homologues were not available at Thompson Island prior to July 5, 2) July 30 to August 8, and 3) October 8 to 21. The latter two time periods were selected because they showed pronounced differences in PCB concentrations between Thompson Island and the other stations. The results of the gross PCB homologue mass at each station, PCB homologue mass lost between stations, PCB homologue percent mass lost, and PCB homologue mass fraction lost are presented in Table I-3-3 and Figure I-3-15. EPA is continuing to assess the results of the analysis to further advance the understanding of the mechanism for PCB transport downstream of the dredging operations.

3.3.5 Analysis of Resident Fish Annual Monitoring Data

The data from the 2004-2008 BMP supplemented by data from the New York State Department of Environmental Conservation (NYSDEC, 2010) resident fish annual monitoring program (1997-2003), and the 2009 remedial action monitoring data were used in this analysis. Temporal trends were evaluated using a regression modeling approach (Field et al., 2007) that accounted for the factors of lipid, size (length), and sex (for black bass), for each station and for available data from each species-station combination from 1997-2008. The potential effects of dredging on tissue concentrations in species collected in September of 2009 (pumpkinseed and forage fish) were evaluated by comparing the baseline monitoring average concentrations at each station for the 2004-2008 period with the results from samples collected during the 2009 dredging. Similar analyses were also conducted on the other species that were sampled during or prior to the onset of full scale dredging to provide an understanding of the potential uncertainties associated with apparent dredging effects that might be inferred from pumpkinseed and forage fish analyses. The statistical evaluation of the potential effects of dredging on fish PCB concentrations in the Upper Hudson River was conducted on both River Section (e.g., River Sections 1-3; or Thompson Island, Northumberland/Ft. Miller, and Stillwater pools) and individual monitoring station bases. There are as many as five monitoring stations within each of the River Sections, and multiple samples are taken from each station. Therefore, EPA's analysis considered both large and small spatial scales within the river to improve our understanding of what the monitoring data indicate regarding PCBs in fish. The results also include comparisons of temporal trends among species and sampling locations, and estimates of trends for data at varying scales of aggregation. Details of the analysis are presented in Appendix I-C. A summary of the findings are as follows:

- Some increases in fish tissue PCB levels were seen in 2009 within the Upper Hudson River when compared to baseline data. The increases in fish tissue PCB levels were predominantly focused to the Thompson Island Pool (i.e., the section of the river where the Phase 1 dredging occurred), with limited evidence of responses downstream.

- There were no statistically significant increases in fish tissue PCBs at the Albany/Troy lower river monitoring station below the Federal Dam at Troy.

- The concentrations of PCBs in Hudson River fish are naturally fluctuating, and this needs to be considered as an uncertainty when evaluating the data from the Phase 1 and downstream areas. The importance of this uncertainty is clearly demonstrated by the fact that the mean concentrations of PCBs in forage fish (minnows) and yellow perch in the Feeder Dam Pool reference site (located upstream of the Phase 1 dredging in Glens Falls) were higher in 2009 compared to the baseline period (2004-2008).

- Variability in fish PCB concentrations was often high (*i.e.,* approximately one order of magnitude range of concentrations within each year) within and among stations, and within reach/section;

- We observed apparent downward trends in the BMP data (2004-2008). The regression statistics on a monitoring station basis indicated that these apparent trends, *over this period*, are weak relative to the interannual variability observed for PCB concentrations in fish tissue (*i.e.,* annual variation was about an order of magnitude). Because these series are of relative short duration, these apparent trends should be interpreted tentatively conditional on future monitoring.

- On a River Section (RS) basis fall collected yearling pumpkinseed were significantly increased in 2009 in the Thompson Island (RS-1) and Northumberland/Fort Miller (RS-2) Pools, and forage fish (minnows) were significantly increased in 2009 only in the Thompson Island Pool. There were only significant statistical decreases shown for the spring-collected resident sport fish (black bass, yellow perch, and bullhead) in 2009 compared to the baseline data.

- On an individual monitoring station basis, tissue PCBs in pumpkinseed were significantly elevated at three out of five monitoring stations in the Thompson Island Pool. Two of these locations were within dredging areas (one each in Rogers Island and Griffin Island river locations), and one was approximately one mile below the dredging near Rodgers Island. In the Northumberland/Fort Miller Pool, the statistical comparisons indicated that the northernmost station within this pool was marginally higher in 2009 than during the baseline period (2004-2008). All other monitoring stations in this pool showed no changes. There were no changes from the baseline levels of PCBs in pumpkinseed collected at any of the five monitoring stations in the Stillwater Pool in 2009 or the Albany/Troy station.

- Overall, the monitoring data indicated that resuspension of PCBs from sediments during dredging affected fish locally, with greatest impact in the immediate vicinity of the dredging activity, but the current data do not support the notion that dredging had an effect on PCB levels in fish more than 2-3 miles downstream of the Thompson Island Pool.

EPA anticipates that any dredging-related, localized body burden increases of PCBs in fish that are observed in the short-term will rapidly return to baseline levels, and continue to decline thereafter following remediation. EPA's reasoning is based on the following:

- Dredging will only occur in a given area for a single dredging season, or a portion thereof. This will be on the order of a few weeks to a few months. In other words, any exposures that are related to the dredging will be brief.

- Tissue concentrations of PCBs in fish from the Hudson River have been shown to decrease rapidly, within 1-2 years, following exposure events, once the source of PCBs is controlled. A recent example is the Allen Mill gate failure.

- Tissue concentrations of PCBs in fish have been shown to decrease rapidly following spikes related to environmental dredging. Some examples in the Region include: Cumberland Bay Superfund Site, Plattsburg, NY; Grasse River, Massena, NY; and, Niagara-Mohawk Site, Queensbury, NY.

3.3.6 Far-field Net TPCB and Tri+ PCB Daily Average Load

The net TPCB and Tri+ PCB 7-day running average loads were estimated for the far-field stations at Thompson Island, Lock 5 and Waterford. The results are presented in Figure I-3-16. For the majority of the project, the 7-day running average net loadings for TPCB and Tri+ PCB at Thompson Island exceeded the Control Levels of 1,080 g/d and 361 g/day, respectively. These levels were initially exceeded during the first week of dredging in mid-May and, except for brief periods in early June, mid-August, and late September, net PCB loadings were between two and four times the Control Level criteria at Thompson Island. A rapid increase in TPCB load was observed starting July 29, 2009, to a peak load of above 8,000 g/d on August 8, 2009, a period that corresponded to high flows at Fort Edward and water column concentrations increasing to above 500 ng/L, prompting shutdown of the dredging operations. After October 27, 2009, the daily average TPCB load at Thompson Island decreased, but estimates were still above the evaluation criteria of 540 g/d. This period coincides with backfill and cap placement and increased vessel movement.

TPCB Loads at Lock 5 and Waterford were significantly lower than loads at Thompson Island. During the periods mid July to mid August, and for the month of October, the TPCB daily loads at Lock 5 were significantly higher than the Control Level. At Waterford, the 7-day average load was less than the Evaluation Level about 50 percent of the time and exceeded the Control Level 20 percent of the time.

Tri+ PCB loads at Lock 5 exceeded the Control Level about two-thirds of the period, and peak loads above 1,500 g/d occurred in early August and late October 2009. At Waterford, the highest Tri+ PCB load occurred close to the end of active dredging when flows were extremely high.

Overall, the 7-day average PCB concentration was exceeded at Thompson Island for the majority of the dredging period. However, although PCB daily loads decreased down river significantly, a concurrent decrease was not observed in solids transport. Therefore, PCB transport was likely not controlled by solids transport, especially given the importance of non-particulate PCB in the near-field. It is likely that other mechanisms controlled the transport of PCB downriver. Far-field transect studies to trace the fate and transport of the PCBs in the various phases were not conducted and a further assessment of these mechanisms cannot be made at this time.

3.3.7 Far-field Seasonal TPCB and Tri+ PCB Load

Minimizing the export of PCB load downriver, particularly at Waterford, was a key metric of the Resuspension Standard. Figure I-3-17 represents the cumulative load at all downstream automated stations. The Resuspension Standard targets for both TPCB (117 kg) and Tri+ PCB (39 kg) were exceeded at all of the downstream monitoring stations. Between May 15 and November 30, 2009, the cumulative load at Thompson Island of 437 kg was about 1.5 times higher than the load at Lock 5 (269 kg/yr) and about 3 times higher than the export TPCB to the Lower Hudson at Waterford (151 kg/yr). While elevated, the 437 kg estimated load for Thompson Island is small relative to the mass of PCB removed (20,000 kg), and is also small relative to total PCB mass in the Thompson Island Pool of 67,000 to 97,000 kg. Estimates of mass of PCB removed are further explained in the Chapter II. Tri+ PCB cumulative loads estimated for Lock 5 (123 kg/yr) and Waterford (61 kg/yr), exceeded the Control Level of 39 kg. However, the cumulative load of TPCB at Waterford did not exceed 1 percent of the mass removed during Phase 1 (*i.e.,* 200 kg for TPCB). The implication of the export of PCBs at Waterford is discussed in Section 3.3.9 below.

3.3.8 Far-field TPCB and Tri+ PCB Mass Lost or Export Rate

The resuspension standard set a mass loss or export loss rate of 1 percent of the total inventory dredged in the Hudson River. The calculation method of the PCB export rate during Phase 1 dredging is given in Appendix I-E. Figure I-3-18a presents the PCB mass dredged from May 15 to October 27, 2009, and the time series of the daily load at the far-field stations. Note that estimates of the dredged PCB mass are based on densities reported by GE in the July 15, 2009 resuspension engineering evaluation report. Figure I-3-18b and Figure I-3-18c present the time series of the PCB export rate at the three far-field stations: Thompson Island, Lock 5 and Waterford, on a weekly and cumulative basis, respectively. At the beginning of dredging, when there was very little productivity, a high mass loss approaching 100 percent was estimated at all stations. This was in part due to debris removal, low volumes of sediment and PCB mass removed and high flows. As productivity increased, the mass loss decreased significantly to values approaching and remaining at 1 percent to 2 percent at Thompson Island. On a weekly basis, the mass loss of between 2 to 3 percent occurred at Thompson Island during project breaks (e.g., July 4th holiday weekend; August 2009 suspension due to federal MCL exceedance; Memorial Day holiday weekend). The mass of PCB lost to the Lower Hudson River during most of the dredging period, as estimated at Waterford, was less than 1 percent.

3.3.9 Assessing the Impact of PCB Export to the Lower Hudson River

Despite the readily measurable increase in water column concentrations in the Upper Hudson, Lower Hudson water column concentrations as recorded by both GE and the NYS DOH (see NYSDOH fact sheet in Appendix I-F) did not increase in response to loads from the Upper Hudson. In particular, there were no discernable increases in Total PCB or Tri+ PCBs at the Lower Hudson monitoring locations near Poughkeepsie, Port Ewen or Rhinebeck (Figures I-3-19). Tri+ PCB concentrations were also unchanged at the Albany monitoring station, roughly 15 miles downstream of Waterford. Increases in Total PCB concentration were observed at this station; however the associated congener patterns were considered unusual for the station and are considered to be an analytical artifact and not representative of an actual increase of PCB concentrations at this location. It is anticipated that concentrations in the Lower Hudson River will continue to remain at baseline levels because concentrations in the Upper River returned to baseline shortly after cessation of all in river activities in December (Figure I-3-20). The general lack of concentration increases in the Lower Hudson is not considered surprising given the extensive inventory already in place, estimated as 80,000 kg by Bopp and Simpson, 1989.

The PCB mass load criteria of 117 kg and 39 kg for TPCB and Tri+ PCB, respectively, represent the Phase 1 pro-rated portion of the total allowable mass (650 kg) that could be transported downstream during the full six year dredging program identified in the ROD. The ROD estimated the mass inventory to be removed was approximately 70,000 kgs. The projected load was set at just below 1 percent of this total or 650 kg. Originally the ROD estimated that 10 percent of the total mass was to be removed in Phase 1, or 65 kgs (650 multiplied by 0.10). Based on the remedial design for Phase 1, it was determined that dredging of Phase 1 areas would remove approximately 18 percent of the mass (not the 10 percent originally estimated), as a result the mass load number was adjusted to 117 kgs (650 multiplied by 0.18) or 257 lbs for TPCB and 39 kgs for Tri+ PCB. While this slight adjustment was made, the larger adjustment to total load criteria (650 kg) was not made at this time, even though the design data indicated a significantly higher mass inventory of PCBs to be removed (115,000 kgs). In hindsight, this adjustment should have been made at the start of Phase 1.

The mass load target of 650 kg established at the time of the ROD should be revised upward. This section presents information explaining why EPA believes the mass load criteria should be revised for Phase 2. The Engineering Performance Standards allowed possible refinements to the standard (USEPA, 2004; Vol.1, Section 4.0). Specifically, the load-based criteria in the Resuspension Performance Standard were to be reviewed and refined if the estimate of mass to be removed was significantly different from previous estimates. The mass estimate to be removed is significantly different as determined during the design (see the Phase 2 Dredged Area Delineation (DAD). Based on the Phase 1 experience, the remedial design's estimate of total mass removal for the project is likely too low. The following language appears in Volume 1, Section 4 of the Resuspension Performance Standard:

> *Prior to Phase 1, the baseline monitoring program water column sampling will be conducted and remedial design sediment sampling will be completed. The additional data from these efforts, collected after the issuance of these standards, will improve the ability to measure exceedances of the Resuspension Standard, but are not expected to change the main criteria of the standard. The acceptable rate of PCB loss and the acceptable water column concentrations are not expected to change as the result of additional data, because these criteria are based on modeling of future impacts and associated risks.*

Further on in the section, it states:

> *As a part of the remedial design, GE is collecting sediment samples throughout the Upper River in order to more precisely define the extent of contamination. These data will be used to revise the estimate of mass to be removed during the remediation. Load-based criteria in the Resuspension Standard will be reviewed if the mass of PCBs to be removed is significantly different from previous estimates.*

There are number of points that should be re-iterated here for clarity. The standard considers the rate of loss (1 percent) and the water column concentrations (350 ng/L and 500 ng/L) to be the main criteria of the standard and that these criteria are not expected to change based on additional data as they are based on modeling of future impacts and associated risks. The Standard considers the load-based criteria to be subject to change based on the sediment sampling data and the estimate of mass to be removed. This is not surprising since exceeding the load target number in a particular year requires that engineering evaluations be performed to try to reduce the mass being transported, but does not require suspension of dredging.

In revising the load based criteria, EPA is not changing the main criteria of the standard, *i.e.,* the acceptable rate of loss (1 percent) and the acceptable water column concentrations, but is applying the acceptable rate of loss to the revised estimate of mass to be removed as allowed by the Standard.

The sediment sampling information and experience from Phase 1 suggest that the load target criteria are subject to refinement as it appears that the mass removed in Phase 1 was actually 1.5 to 1.8 times greater than the estimated mass to be removed. The actual mass removed in Phase 1 exceeded the projected mass to be removed by a factor of 1.5 and also exceeded the adjusted mass removed by a factor of 1.8 (please see Table II-3.1-2). Additionally, further refinement may be necessary as there was some mass inventory left behind. It should be noted that the adjusted mass number was calculated by not counting mass from areas that would not be dredged due to necessary offsets such as rip rap areas, bridge piers, walls, tree roots, and shoreline areas that were in the original design estimates and is further explained in Section II-2.3 and Table II-2.3-2.

During Phase 1 dredging, the actual PCB mass removed was higher than the estimated mass prior to dredging. During Phase 1, only 10 out of 18 CUs originally targeted for dredging were dredged. The estimated mass of PCB based on the sediment samples collected during the sediment sampling and analysis program (SSAP) for the 10 CUs dredged was approximately 13,000 kg (or 11,200 kg on an adjusted basis). However, the actual TPCB mass removed during dredging was approximately 20,000 kg, a 54 percent increase based on the original design estimate and an 80 percent increase based on the adjusted mass estimate (see Chapter II, Section

3). Note that GE's estimate of mass removed (16,300 kg) is lower than EPA's but both GE's and EPA's estimates are higher than the original design estimate. The calculation of mass removed is discussed further in the Residuals Chapter. The PCB mass removed increased primarily because the depth of contamination was deeper than estimated by the SSAP cores. Based on the results GE reported in the design, EPA estimated a total remedial inventory of 115,000 kg of PCB. Given the experience of Phase 1 relative to GE's design estimates, it is clear that the design estimates are substantively low, suggesting load criteria may be a moving target and may continue to need further revision.

Based on the Phase 1 experience, EPA's best current estimate of the amount of PCB mass to be removed from the sediments is 1.5 to 1.8 times the estimated mass of 115,000 kg from the sediment sampling program. This results in a range of mass to be removed of 170,000 kg to 210,000 kg. The 1% loss rate would equate to a load of 1700 kg to 2100 kg for the project.. The load based criteria for Phase 1 should have been approximately 200 kg (based on current estimates it is likely that the mass removed in Phase 1 is approximately 10 percent of the total PCB mass to be removed for the project).

The fact that the load based criteria are approximately 3 times higher than developed based on the ROD estimate of mass to be removed is not surprising. There are several lines of evidence that do put this further into perspective (see Appendix G for details):

- In the areas (CU's 1-8, 17-18) dredged during Phase 1, the pre-dredge estimated volume targeted for removal was approximately 150,000 cubic yards of PCB contaminated sediments. The actual material removed from these areas almost doubled and is closer to 300,000 cubic yards.

- Prior to Phase 1, the baseline loads as forecast by EPA's HUDTOX model were substantially lower than those actually observed for the period 2004 to 2009. Although analysis of model and actual data are still ongoing the following observations have been made:

    - For the Waterford station, the model loads were about 2.5 to 3 times lower than the actual loads during 2004-2009. See Figure I-3-21.

    - Estimates of loads at Waterford based on USGS and GE data for the period 1995 to 2008 show no statistically significant decline. A first order regression through the data yields a "half life" of 99 years for the decline of the load, although this rate is not distinguishable from no change with time at all. The model forecast curve during the period 1998 to 2008 was equivalent to a 5 to 8-year half life (see Appendix G).

- The surface sediment concentrations (based on the 0-2 in SSAP samples) are much higher than model predictions (Figure I-3-22). While it was conjectured that the contaminated sediments were "being buried", the reality is much different. The measured Tri+ surface sediment (based on the 0-2 in SSAP samples) concentrations from 2002-2007 exceed the upper bound of model predictions for 2003 (Field, et al., 2009). Although EPA did not endorse this study, analyses by Field et al. (2009) also showed that the Remedial Design Tri+ PCB concentrations in surface sediment exceeded surface concentrations in 1998 GE data for Thompson Island and EPA model estimates for other river sections.

Based on the above discussion the load limit at Waterford for Phase 1 should have been 200 kg. The impact of this adjustment to the load has been analyzed by EPA (see Appendix G).

4 ANALYSIS OF SPECIAL STUDIES RESULTS AND RESUSPENSION CONTROL MEASURES

This section analyzes the results of special studies that were conducted to determine the effect of several factors on dredging (Sections 4.1 through 4.5), and also presents an evaluation of resuspension control measures implemented during Phase 1 (Section 4.6). A number of special studies were conducted to further evaluate sediment and PCB resuspension measured during the dredging project. Two of these studies, the Near-Field PCB Release Mechanism Special Study (Section 4.1) and the Non-Target Downstream Area Contamination Special Study (Section 4.3), were planned as a part of the dredging program and are documented in the RAM QAPP (GE, 2009a). Additional studies as described below were developed as part of engineering evaluations conducted to understand the sources, transport, and fate of PCB released during the project. These additional studies included: PCB Near-Field Transect Studies (Section 4.2), Effect of DNAPL during Dredging (Section 4.4), and Decanting Dredge Bucket Water as a Source of PCBs (Section 4.5).

4.1 Near-Field PCB Release Mechanism Study

The Near-Field PCB Release Mechanism Study was conducted to assess the nature of the primary release mechanism in the vicinity of dredging operations. The DQO of this study was to evaluate the extent to which the PCBs released by remedial operations are dissolved or associated with suspended matter to determine whether near-field TSS concentrations can be a reliable indicator of PCB releases.

Dissolved and particulate samples were collected along transects located in the vicinity of the EGIA dredging activities. Water samples were filtered in the field at the time of collection, and the filters and the filtrate submitted for analysis. Table 4-1 summarizes the observed PCB in suspended and dissolved phase and TSS Concentrations. The PCB homologue patterns for suspended and dissolved PCBs are shown in Figure I-4-1. The observations from these results are as follows:

- This study found that the PCBs in the water column were predominantly in the dissolved form, averaging over 90% of the total PCBs
- The dissolved PCB fraction was dominated by mono- and di- chlorinated congeners, while the particulate fraction is dominated by tri- and tetrachlorinated congeners.

EPA's initial analysis in its draft report was based on incorrect lab POC data. GE identified the error and provided EPA with the correct POC data on March 4, 2009. EPA is currently analyzing the data to understand whether the kinetics of PCB desorption from the sediments could support the dissolved phase concentrations observed in the near-field, and to determine the extent to which NAPL affected the partitioning in the water column.

4.2 PCB Near-Field Transect Studies

During dredging activities, cross-sectional grabs for Total PCBs (and dissolved PCBs in most cases) and TSS concentrations were collected along transects perpendicular to river flow during May, July, August, September, and October. The objective of these transect studies was to evaluate the near-field impact of dredging-related activities relative to observations at Thompson Island far-field station in the following three areas: 1) East Channel of Rogers Island (ERI), 2) West Channel of Rogers Island (WRI) and 3) the area to the east of Griffin Island (EGIA). However, it is important to note that direct comparisons to Thompson Island far-field station PCB concentrations cannot be made because the transect data were snapshots in time (typically 30 minutes or less per sample collection event) while the observations at Thompson Island were 24-hour composites.

The transect stations sampled during Phase 1 were located in the following areas (Figure I-4.3):

- Downstream of CU-5 and CU-6 in the West Channel of Rogers Island (WRI North)
- Below CU-1 in the east channel (ERI North)
- Terminus of the west channel (WRI)
- Terminus of the east channel (ERI)
- South of CU-16 (NTIP)
- Upstream of CU-17 (EGIA-Up)
- Downstream of the CU-18 sheet piling containment (EGIA-DS)
- Downstream of CU-18 (EGIA-Down)

In addition to these transect locations, there were two locations where grab samples were obtained in the East Griffin Island area, including: a location within the sheet pile containment in CU-18 (EGIA-Inside Sheeting), and a location within the silt curtain in CU-18 (EGIA – Inside

Silt Curtain). Not all locations were sampled during each round of sampling. The date of sampling and in-river activities when the transect samples were collected are summarized as follows:

- 5/22/09 - Debris Removal in CU-2, CU-4, CU09, CU-10; Demonstration/Access Dredging in CU-9
- 5/25/09 – No Activity (Memorial Day shut down)
- 5/26/09 - Debris Removal in CU-13, CU-14, CU-15; Demonstration/Access Dredging in CU-9; Debris Removal in CU-18 started late in day
- 5/28/09 - Debris Removal in CU-2, CU-3, and CU-10; Demonstration/Access Dredging in CU-9
- 7/23/09 – Dredging in CU-1, CU-3, CU-4, CU-6, CU-7 and CU-18 (within and outside the sheet pile area)
- 8/10/08 to 8/11/09 – No Activity
- 8/12/09 - Dredging in CU-1, CU-4, CU-5 and CU-18 (within the sheet pile area)
- 8/14/09 - Dredging in CU-1, CU-2, CU-4, CU-5, CU-8, CU-17, and CU-18
- 8/17/09 - Dredging in CU-1, CU-2, CU-4, CU-5, CU-6, CU-8, CU-17, and CU-18
- 8/22/09 - Dredging in CU-1, CU-2, CU-4, CU-5, CU-6, CU-8 and, CU-17 conducted two days after the start of the CU-18 southern sheet pile containment wall removal (occurred 8/20-10/2)
- 10/21/09 - Dredging in CU-1, CU-8, and CU-18. Backfilling in CU-2, CU-3, CU-6, CU-7 and CU-8

Two transect sample types were collected:

- Equal volume aliquots along the cross section to form a single composite sample.
- Individual samples from several nodes along each transect were collected and analyzed separately for PCBs and TSS. In these cases, flow proration factors reported by GE for each transect node where used to estimate a composite concentration. The node proration factors were established based on a single round of instantaneous flow velocity measurements by GE. These proration factors were assumed to be applicable at various flows encountered during subsequent sampling events. It is unclear how this assumption affected load calculations during these studies.

To estimate instantaneous loads for transects located in the east and west channels at Rogers Island, flow proration of the USGS flows at Fort Edward provided by GE were used. GE (GE, 2010) estimated a proration factor of 3.74 percent of the USGS flow at Fort Edward for the east channel at Rogers Island during the period that the rock dike was in place and 96.26 percent for the west channel.[2] The use of fixed proration factors is an oversimplification of the complex flow conditions that resulted from the rock dike installation, as explained here. Prior to the installation of the rock dike, about one-third of the flow went through the Rogers Island east channel. The combination of the flow restriction imposed by the rock dike at its head and the rapid changes in river flow that occurred most days due to operation of an upstream power dam caused the water surface elevation at the downstream end of the east channel to change more rapidly than by the rock dike. This resulted in flow reversals in the east channel as water at a higher head in the main channel of the river caused water to move into the east channel. As river flow subsided, the head in the river dropped and water was then released from the east channel.

4.2.1 Results and Discussion

Concentrations of Total PCB, Dissolved PCB, TSS, Tri+ PCB to Total PCB ratio, mean flow at Fort Edward during sample collection, and assigned flow per node on each transect are given in Table I-4.2. A summary of the PCB concentrations and instantaneous loads per transect are given in Table I-4.3. Furthermore, the PCB homologue patterns of each sample analyzed by the mGBM are given in Figure I-4.4.

The results of the transect sampling indicate that the dissolved fraction of PCB ranged from 13 to 100 percent, averaging about 68 percent. Although the dissolved phase fraction is lower than that observed in the Near-Field PCB Release Mechanism Special Study (see Section 4.1 above), both programs highlight the dominance of dissolved phase release during dredging and related activities. The homologue profiles (Figure I-4.4) and Total PCB/Tri+ PCB ratio indicate that the dissolved and whole water PCB samples collected during the transect studies differ in composition. The Total PCB/Tri+ PCB ratio for the dissolved phase averaged 5.8, while the average for the whole water samples was 3.7. Thus, the samples analyzed for whole water PCBs are more highly chlorinated than the dissolved PCB samples, highlighting the preference of the higher chlorinated congers to remain in the particulate phase. As the water column content is transported to Thompson Island, the Total PCB/Tri+ PCB ratio increases, especially at higher flows, indicating that the lighter fractions were lost, probably through volatilization. The results of transect concentrations and instantaneous loads for each month of sampling are discussed below.

<u>May Transects</u>

The May transects sampling did not follow a time of travel approach, and therefore the load differences must be interpreted with caution. In general, the west channel contributed higher

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[2] The precision of these factors are as reported by GE (2010). EPA is not aware of any measurement technique that would provide this level precision for a water body of this size for the number of measurements collected.

loads to the river at the time of sampling, because the majority of the flow passes on this side of Rogers Island. In the month of May, debris removal was the main activity, with limited dredging in CU-9, and the higher concentrations observed relative to baseline conditions suggest that debris removal had a major impact on loads in the river early in the dredging project. For instance, in the Rogers Island east channel, where debris removal was the only ongoing activity, a concentration of TPCB of above 4,000 ng/L was observed in the May 28 sampling event.

On May 22, 2009, concentrations along the west channel transect were not fully mixed and it is unclear whether the higher TSS concentrations along the western shallow end of the transect were due to dredging or resuspension of sediment by the sampling vessel. The higher TSS observed in the west channel of Rogers Island would lead one to conclude that solids settling occurred between Rogers Island and the transect at NTIP. However, such a conclusion cannot be supported since the sample at NTIP was collected about five hours after the West Rogers Island (WRI) transect sample was collected. At flows above 8,000 cfs, the observed plume at WRI would have already gone past the NTIP station by the time the NTIP sample was collected.

During the Memorial Day holiday weekend (May 25 sampling), there were no project activities and concentrations in the west channel and NTIP of approximately 30 ng/L were similar to background values observed at Thompson Island. Concentrations in the east channel were twice the background value suggesting that activities during the previous days still had an impact on this area since the low flows, due to the rock dike barrier, resulted in a slower flushing of the east channel.

The variability in concentrations between transect nodes suggests that the equal volume compositing, done at some stations later in the transect studies, are likely biased. For example, the May 22 transect at WRI the straight average of the concentrations at all the node (an equal volume composite average concentration) of 348 ng/L. However, when the fraction of flow through each node is considered, the flow-weighted composite average is 209 ng/L, a factor of 1.6 times lower than the results obtained from equal volume compositing. This uncertainty strongly indicates that the transect data must be interpreted with caution as the lack of mixing along the cross section might be obscured if equal aliquots are taken to form a sample, as generally was done for EGIA-UP and NTIP transects.

<u>July Transect</u>

The July 23 sampling event started from East Griffin Island-Down and proceeded upstream, again not following a time of travel approach. During the sampling, flow increased by as much as 900 cfs. The key observations from these transect results are as follows:

- Over 70 percent of the PCB in the near-field area is in dissolved form.
- The instantaneous contribution from ERI was about 55 percent of the contribution from WRI.

- TPCB concentrations were largely unchanged from NTIP to EGIA-Down with the exception of the observation within the sheet piling in CU-18. TPCB concentrations within the sheet piling where dredging was occurring were over 21,000 ng/L. Despite dredging within the sheet piling and outside of the sheet piling in CU-18 there was little or no impact in water column concentrations between NTIP and the EGIA-Down transect.

- Because of variability in flow, and uncertainties related to time of travel differences, sample compositing, the analytical measurements and presence of NAPL, instantaneous load differences of about 12 mg/sec or more cannot be discerned as significant during the July transect studies.

August Transects

The shutdown of the dredging operation in early August, and the subsequent phased approach to restarting the dredging provided an opportunity to evaluate the contributions of dredging activities within the different CUs to downstream PCB flux. The sampling was conducted along transects throughout the Phase 1 dredge areas. In addition, single samples were collected from inside the containment areas within CUs 17 and 18. The August 2009 sampling attempted to follow a pseudo time of travel approach; transects were sampled upstream to downstream starting in the upper Rogers Island east channel. The objective was to follow the same parcel of water moving down the river, although flow variations and associated time of travel changes as well as sample timing restraints precluded a true time-of-travel study.

The dissolved PCB phase in August samples ranged from approximately 13 to 100 percent (average 69 percent) of the whole water PCB observation, with lower dissolved percentages associated with higher TSS concentrations. TSS data showed little evidence of dredging-induced sediment resuspension in the Rogers Island west channel, remaining low during the different sampling events. TSS concentrations were significantly higher downstream of CU-16 than at upstream locations on three out of the five sampling events in August. As there was no active dredging between Rogers Island and CU-16, and the river flows remained seasonably low during the evaluation period, these increases in TSS have been attributed to sediment resuspension caused by the operation of the sampling vessel in very shallow water on the west side of the river at the NTIP transect. The TSS concentration at Griffin Island outside of the containment areas remained consistently low throughout the sampling events. The impact of the sampling boat induced resuspension compromises the evaluation of changes between Rogers Island and East Griffin Island, since this may be a factor even when TSS differences do not appear to be large. The general observations from the August transects are:

- Increases in concentrations, primarily in dissolved form occurred between the northern and southern stations of Rogers Island west channel and east channel.

- Although concentrations in the east channel were significantly higher than those in the west channel, the rock dike was effective in reducing the flows to an estimated 3.74 percent of the total river flow and consequently limited the loading from the east channel to the main stem of the river.
- During the August sampling events concentrations from individual nodes at the East Griffin Island-Up transect were not available. The single composite concentration reported might be an equal volume composite sample, and therefore it is not clear how concentrations varied along the cross section at this location. Notably, differences in concentrations between the East Griffin Island-Up and the East Griffin Island-Down transects are reflective of activities going on in CU-17, within and outside the sheet pile containment in CU-18, boat traffic, and the release of PCB from NAPL. Because of the complex interactions among these factors, their relative contributions cannot be easily discerned. Concentrations within the sheet pile containment in CU-18 are several orders of magnitude higher, but loss of this water to the river was generally unimportant since there is very little increase in the transport of PCB downstream of the sheet pile containment. In the August 14 sampling event, a load <u>loss</u> occurred between the East Griffin Island-Up and the East Griffin Island-Down transects, suggesting that the uncertainties in these transect data and the daily variability in near-field concentrations preclude an assessment of the whether concentration and load differences between the upstream and downstream transects are statistically significant. During dredging in the sheetpile area, there were PCB and TSS losses through windows that were cut into the sheet piling to equalize head differences.[3] PCBs were also released when the sheet piling was removed, but a gradual removal of the sheets did not cause a significant spike in the downstream load at the Thompson Island Far-Field Station.

<u>October Transect</u>

Sampling conducted on October 21 showed an upstream to downstream gradient in PCB concentrations, but the timing of the sample collection precludes inference on whether the instantaneous load gain can be traced to the same parcel of water as it was transported downstream. Sampling in the east and west channels occurred between 8:00 and 9:00 in the morning. Two hours later, sampling was done in the East Griffin Island-Down transect. Sampling in the intermediate transects at NTIP and in the EGIA-UP transect followed an hour after that. The differences in instantaneous TPCB concentrations and loads from upstream to downstream were within the uncertainty bound of 12 mg/sec established in July due to uncertainty in time of travel and other factors. Furthermore, there were no TSS data associated with the sampling event, so it is unclear whether local vessel resuspension affected the TPCB

[3] It is unclear to EPA why these windows were cut in the sheet pile walls since the purpose of the sheet pile was to isolate the water within the sheet pile to the maximum extent possible.

concentrations. In their draft report (GE, 2010), GE contends that the magnitude of the PCB transport due to dredging can be determined from the PCB concentration gradients across the dredge areas. While the observations of water column concentrations in the TI Pool clearly show the impacts of the Phase 1 operations in general, it is also clear from the above analysis that local measurements are too variable and inconsistent to serve as a basis for local loading estimates. Specifically, high variability in the differences in the instantaneous concentrations preclude their use in meaningful calculations of instantaneous load.

4.3 Non-Target Downstream Area Contamination Study

Performance of a special study to measure the amount of resuspended material resulting from dredging operations that settled in the areas immediately downstream was specified in Section 9.3 of the RAM QAPP (GE, 2009a). The study was performed downstream of EGIA as specified in the RAM QAPP. However, other locations specified in the RAM QAPP were modified to accommodate project logistics, as documented in the Data Compilation Report (GE 2009d).

It was specified in the RAM QAPP, that sediment traps would be placed downstream of CU-18 (EGIA), approximately two weeks before dredging was to start in that area, to establish baseline conditions. However, this baseline was not collected. The lack of baseline data limits the interpretation of the sediment trap data, especially since SSAP data suggested that surface sediments are much more contaminated than estimated at the time of the ROD.

The Hudson River is a dynamic system in which sediment moves around on a routine basis. Before examining the results of the Non-Target Downstream Area Contamination Special Study, it is useful to examine the movement of solids and the associated PCB mass. The bathymetric surveys conducted in 2001, 2005 and in 2009 strongly reinforce this observation as there was approximately a 35,000 cubic yards net loss of sediments. The comparison of bathymetric surveys from 2001 and 2005 showed 24,000 cubic yards of net erosion in the 10 Phase 1 CUs. The net erosion from 2005 and 2009 was upwards of 11,000 cubic yards prior to dredging in the 10 CU’s actually completed in Phase 1. As discussed in Chapter II, Section 2.6, these bathymetric changes indicate a highly variable distribution of depositional and erosional areas on the river bottom. The analysis shows that the area east of Griffin Island experienced erosion on the order of 6 inches with some isolated pockets experiencing up to 1 foot of erosion.

The magnitude of the PCB loss associated with the net sediment movement can be estimated from the net volume moved and the average surface concentration in the 10 Phase 1 CUs. Given the net loss of 35,000 cubic yards, a sediment density of 0.8 g/cc and an average TPCB surface concentration in the top 2 inches of the Phase 1 CUs of 75 mg/kg, the net erosion over the 8 year period represents a net loss of about 1,600 kg. The estimated gross erosion volume during this period represents a flux that is 25 to 75 percent greater. In comparison, the net release of PCBs due to all dredging activities in Phase 1 was estimated at about 430 kg based on the TI station.

Thus, the sediment movement due to erosion and deposition over the past 8 years alone represents a PCB flux about four times greater than the releases due to dredging. Whether the erosion-related flux occurs on an annual basis or is predominately due to a limited number of high flow events is not relevant to this discussion, since it clearly indicates that contaminated sediments are being moved within the system. This movement of sediment includes highly contaminated sediments.

To examine suspended solids related to dredging, cylindrical sediment traps were anchored in the river downstream of CUs 4 and 18 to capture sediments transported within the water column. The rate of sediment collection in the traps was used by GE in their draft report to establish a sedimentation rate during dredging to the river bed of about 2 cm/year (GE, 2010). This method of establishing settling or sedimentation rates, based on sediment trap collection rates, is not supported by the technical literature especially for riverine and shallow systems where these devices over-trap particles in even moderately turbulent waters. Kozerski (1994) and Kozerski and Leuschner (1999) reported that settling flux of particulate matter measured by traditional cylindrical sediment traps in turbulent waters considerably exceeds the natural rates by a factor of up to 5 times. The disappearance of turbulent diffusion and bottom shear stress within the traps causes the high rates of capture. Implicit in GE's use of the sediment trap data is the assumption that the settling rates are net settling of particles released by dredging. GE further assumes that there is no local resuspension due to the high flows in 2009. Given that the average surface sediment (0 - 2 inches) concentration in the Northern Thompson Island Pool is approximately 17 ppm Total PCB and 75 ppm Total PCB in the surface sediments of the Phase 1 CUs, resuspension of this material by other activities including boat traffic can explain the concentrations of the materials collected in the sediment traps. Furthermore, fine sediments that were released high in the water column during bucket decant under velocity greater than 20 cm/sec are likely transported downriver and can significantly contribute to particles collected in the traps. There is also some concern that sediment traps were placed in an area south of CU-18 that was used as a turning basin for vessels and large barges. Figure I-4.5 shows the boat traffic during the sediment trap deployment period. It can be seen from the figure that the boat traffic was heavy during this time, especially near the sediment traps closest to the edge of CU-18. Thus the gradient in sediment collection that GE observed might be related to variations in intensity in boat traffic around the traps.

Since baseline sediment trap data was not collected, GE decided to conduct some additional core collection in non-target areas. Please see Common Appendix for email transmitting initial EPA comments and thoughts on the sediment trap study and subsequent core collection. The follow-up coring event was planned to take up to 27 samples and a number of co-locates. However, only 6 cores were collected and no co-locates (which would have provided an additional perspective on variability in the system) were collected. The lack of recently deposited sediments at the other 21 sites precluded the GE field team from collecting sediments in the other

21 locations. Data for 5 out of the 6 sediment cores indicate sediment concentrations increased over prior sampling in the area and GE concluded that significant accumulations of resuspended materials were settling in areas outside the CUs. No radionuclide analysis was conducted on the sediments to determine their age and confirm that they were recent deposits. Due to the high degree of variability in surface sediments, these results do not provide a statistically significant difference over the original observations. An exact 95 percent confidence interval for the proportion of locations that increased with 5 of 6 increases is 0.36 to 0.99 (Clopper and Pearson, 1934). This interval captures 0.5, which is the null proportion under the hypothesis of no change, and therefore the results are not significant. Also, the sampling locations appear to be biased toward low concentration areas, pre-loading the follow-up concentrations to be higher than the initial. A proper sampling design with an unbiased selection of locations and adequate sampling size are required to test this question of whether concentrations in the surface sediments outside the CUs dredged increased. Finally, the average difference in concentrations (17 mg/kg) between the historical and recent sediment concentrations in the 6 sediment cores, is less than the mean absolute difference for co-located surface sediments in the upper 0-2 inches. The relative percent difference for all co-located surface sediments in the SSAP program in Phase 1 dredging areas is approximately 80 percent. This indicates that the differences observed in the 6 locations are not different from the natural variability, and thus are not significant.

An alternate perspective on the issue of settling of resuspended material can be obtained from the post-dredge sampling of each CU. Evidence of resuspended sediments re-settling after dredging should be apparent in the samples collected after each dredging pass since each CU is the local center of dredging related resuspension . There was very little evidence of a residuals layer above the surface sediment cores. If PCBs of significant concentration are being evenly redistributed by dredging then the likelihood of an inventory node being converted to less than 1 mg/kg on a single pass, without a required residual pass is unlikely. Given this, there should be almost no nodes less than 1 mg/kg after the first dredging pass which removed inventory everywhere. After the first dredging pass, 443 nodes were sampled: 33 nodes were abandoned, 147 nodes were determined to still contain inventory, and 240 were residuals (meaning 6 inches or less of contaminated sediment). If resuspension caused redistribution of PCBs, none of the residuals nodes should be less than 1 mg/kg; however, 50 nodes (20 percent of the 240) were less than 1 mg/kg Tri+ PCB. Having 20 nodes go directly from inventory to less than 1 mg/kg within the CU boundaries shows that the process of evenly depositing resuspended PCBs is likely not occurring. Moreover, most nodes within the CUs were able to achieve levels compliant with the Residual Standard, again indicative of the lack of extensive redeposition as most CUs were open, dredged and tested within the same period of time.

GE's also asserted that the higher than baseline PCB load levels in the river after dredging ended were due to the redistribution of sediments on the river bottom. It should be noted that post dredging PCB concentration at all the water monitoring stations returned to normal baseline conditions once all in river activities ceased in December. As a result it is much more likely that the return of the river to baseline conditions was a result of cessation of vessel traffic associated with the completion of the backfill/capping operations and other necessary activities at the end of the season.

Overall, the sediment traps and accompanying coring program failed to confirm that any important re-contamination occurred in non-target areas during dredging. The analysis of the post-dredging coring results shows that redeposition of PCB contaminated sediments within the CUs themselves does not blanket the entire CU, despite being at the center of dredging-related resuspension. Thus settling of PCB contaminated sediment is considered a minor contribution that may affect areas proximal to the operations but is unlikely to affect broad areas of the river bottom. It is likely that additional controls could be implemented if redistribution of sediments was an issue.

4.4 Effect of DNAPL during Dredging

During Phase 1, oil sheens and NAPL "blooms" were frequently observed as a result of dredging activities in the east channel at Rogers Island and at EGI. Field personnel provided descriptions of these oil sheens indicating that they typically appeared iridescent near their core and silver outside the core of the sheen area. The thickness of these sheens is not known since there were no direct measurements taken of the NAPL layer over the course of Phase 1. However, GE contends in its draft report (GE, 2010) that the color of the sheens suggest thicknesses in the range of 0.1-0.3 μm (http://www.mms.gov/tarprojectcategories/remote.htm). Review of this reference does not support this assumption. This reference states: "Observers are generally able to distinguish between sheen and thicker patches of oil. However gauging the oil thickness and coverage is rarely easy". It further states "All such estimates should be viewed with considerable caution. Most difficult to assess are water-in-oil emulsions and viscous oils like heavy crude and fuel oil, which can vary in thickness from millimeters to several centimeters."

GE attempted to collect water samples when sheens were present to assess the PCB concentration of the sheen layer. In each case, a wide mouth sample jar was used to skim the surface of the water. Table I-4.4 summarizes the results, which range from 2,210 ng/L to 393,000 ng/L. Duplicate sampling results, which are indicated by the parenthesis, indicate large disparities that reflect the difficulty in collecting representative samples. However, the high PCB concentrations observed are several orders of magnitude greater than water column concentrations under baseline conditions. Such concentrations likely reflect the presence of a pure PCB product as opposed to an organic substrate that PCB partitions to. A serious limitation to these sampling efforts was that the oil phase was not separated from the sample water in the sample jar for separate analysis and fingerprinting, making it difficult to evaluate the impact of the oil phase on the dredging project.

The possible presence of a pure, or nearly pure, PCB NAPL in this system is consistent with the use of PCB as the dielectric fluid in capacitor production at the GE plant sites in Fort Edward (1946 to 1977) and Hudson Falls (1952 to 1977). PCB oil was received from Monsanto, refined on site, and placed in capacitors by flood filling. Wastewater from GE plant operations containing PCB liquid was discharged without treatment to the Hudson River from both plants until 1977. The NAPL density of about 1,385 kg/m3, typical of Aroclor 1242, which is the dominant component of NAPL in the vicinity of the river, has been reported (GE, 2001). The NAPL-water interfacial tension was assigned a range of values spanning from 5.9 dynes/cm to 28.5 dynes/cm. A recent study on the status of the Fort Edward Plant Site former 004 Outfall #5-58-004 (GE, 2008), presented PCB concentrations in the NAPL ranging from 255 to 1,240 ppm, with an average of 860 ppm. These NAPL concentrations suggest that the water samples collected in the river during Phase 1 by GE are diluted by a factor of at least 1000, and also indicates that small oil droplets have the potential to significantly affect sample variability. Furthermore, it is likely that the surface tension in the oil is enough to float it up temporarily to the surface, but its higher density will ensure that it sinks back to the river bottom where it is slowly released to the water column. Oil droplets and sheens were routinely seen by field personnel downstream of dredging operations.

Using a concentration of 400,000 ng/L (0.4 ppm) and an assumed oil thickness of 1 cm, GE (2010) estimated that it would take 140 acres of oil to explain the PCB load at Thompson Island. This calculation makes inaccurate assumptions about the PCB content in the NAPL and its thickness. However, if the concentration of the NAPL is 255 ppm, the lower bound of observed concentration for this product, a thickness of 1 cm results in 10 kg/acre of NAPL. Under these conditions, less than 4 acres of NAPL over the entire dredging period are required to explain the net PCB load at Thompson Island. This simple sensitivity analysis highlights the importance of the NAPL phase during the Phase 1 dredging, and supports the premise that the release of PCB NAPL from sediments likely played a significant role in elevating water column concentrations during Phase 1 dredging.

4.5 Decanting Dredge Bucket Water as a Source of PCBs

During Phase 1 dredging, particularly early on in the project, the dredging contractor attempted to minimize the amount of water being placed into the hopper barges by decanting back to the river the water portion that was collected in the dredge bucket. In addition, when mini-hopper scows were used in shallow water areas, the dredging contractor routinely decanted water from the bucket back into the river before emptying the sediment, and the rest of the contents of the dredge bucket, into the scows. According to GE (2010), decanting the dredge buckets was done for safety reasons, to prevent the barges from becoming unstable due to excess water in them.

To assess whether decant water was likely to affect the PCB concentration transported downstream of the dredging operation, GE conducted three rounds of sampling on August 13, 16, and 19, 2009, in CU-5, CU-2, and CU-17, respectively. For each event, four samples were collected around each dredging operation targeted for sampling. Before the sampling was conducted, dredging operations were suspended for 10 minutes to allow the immediate downstream plume to clear. After 10 minutes, the sampling boat was positioned approximately 50 feet downstream of the dredging location. The intake of a submersible pump was set at the mid-depth of the river at that location and the pump was started. The sample tubing was purged until the field parameters being measured at the discharge from the tubing stabilized and then the sample was collected. Once this downstream sample was collected, the field crew boarded the dredge and dredging resumed. An extendable pole with a stainless steel pail was used to collect two samples of decant water from the dredge bucket. Once the first bucket bite of the sediments was removed from the river the first sample of the water escaping between the bottom edges of the dredge bucket was collected into a sampling pail. A second sample was collected into a sampling pail on the subsequent bucket bite from water leaving the side of the closed bucket. Once the bucket samples were completed, dredging resumed as normal and a second downstream water column sample was collected five minutes later to approximate the travel time to the sampling location, 50 feet downstream of the dredging location. Samples were submitted for whole water and dissolved PCBs analysis, using the modified Green Bay method, and TSS analysis. The samples for dissolved PCBs analysis were filtered at the laboratory.

Table I-4.5 presents the measured concentrations of whole water PCBs, dissolved PCBs and TSS from the three sampling events. Whole water and dissolved PCB concentrations were elevated in the decant water sample coming from the dredge bucket and in the river sample after the bucket collected sediment and decanted the water. While the results suggest significant inputs of TSS and PCBs from the decant water, the results of this sampling are inadequate to separate the water column effect of the bucket decant procedure and estimate its impact during dredging. The sampling is not representative of all conditions, particularly in cases where NAPL was likely present. For example, decanting a few drops of PCB NAPL that are loosely held within the sediment matrix can significantly impact the flux of PCBs downstream of the dredging. The sampling also suffers from the fact that the plume generated in the near field is likely gone before the second water sample is collected at 50 feet, precluding an evaluation of the full extent of the disturbance and the release. On August 13, 2009, the average velocity in CU-5 was 2.1 ft/sec (0.63 m/sec), meaning that a bottom-disturbed plume would take 25 seconds to be transported a distance of 50 feet. Thus the decant plume and the bottom plume from the bucket test were several hundred feet downstream, well past the sampling station when the in-river near-field water sample was collected five minutes later. Notably, the concentration in the near field had increased nine fold over baseline, corresponding to a nine-fold increase in the near-field instantaneous PCB load. However, this load increase unrelated to the bucket water test event and is instead attributed to both bottom disturbance and bucket decant residual of subsequent bucket dips. As a result, it is not possible to separate the two components based on the experimental design.

The bucket decant sampling in CU-2 on August 17, 2009 did not show a significant change in the water column in the near field relative to conditions before the decant experiment. This is likely due to the slow flushing of the water column within the Rogers Island east channel. The sampling done on August 19, 2009 showed a factor of three increase in water column PCB concentrations in the near field, but it is also likely that the plume created during the dredging and decant had travelled beyond the 50 foot sampling distance, given an average velocity in the vicinity of CU-17 of 0.23 ft/sec (0.07 m/sec) and the seven minutes that elapsed between the collection of the side of bucket sample and the sample 50 feet away. In this time, the parcel of water containing the release of interest would have moved approximately 97 feet downstream, roughly twice the distance from the dredge head as the sample collection point.

To estimate the impact of bucket decant, GE used a simple partitioning approach to determine the mass of PCBs in an estimated decant volume. Based on this approach GE estimated the total contribution of bucket decant to the net load at Thompson Island of about 0.5 to 3 percent. This calculation assumes that the only phase of PCBs contributing to the water column is the particulate phase from the sediments resuspended. Therefore, the calculations of bucket decant contribution by GE (2010) are likely biased low, as NAPL presence was widespread during Phase 1 dredging and not included in this contribution. Note that the TSS concentrations in the decant water are highly variable and orders of magnitude higher than ambient conditions. With higher velocities due to high flows in 2009, the finer grained particles contained in the bucket decant water are likely to be transported downriver, affecting downstream loads. A simple sensitivity analysis can shed light on the range of possible loads originating with decanting of dredge buckets. If the high TSS released to the water column from the buckets resulted in an increase of TSS in the water column of only 1 mg/L (a nominal minimal observed increase), then this increase combined with average concentrations of dredged material (80 ppm in WRI, 150 ppm in ERI, and 250 in EGIA), would have resulted in PCB water column concentrations of at least 80 ng/L. This concentration is significant given that the average water column concentration at Thompson Island during dredging was ~ 215 ng/L during dredging. GE estimated a total bucket decant water volume of 166,000 cy between May 15 to August 22, 2009. In a similar fashion, if 0.004 percent of this volume is DNAPL with average PCB content of 10 percent (a ten-fold dilution of the original oil released by GE) then the total additional mass of PCB from the DNAPL is about 500 kg. This estimate is comparable to the estimated mass of PCBs transported past the TI station. Note also, that the higher TSS concentrations emanating from the bucket decanting may also impact the sediment trap data and downstream redistribution of sediments. A similar concern may surface with less productive bucket bites (*i.e.*, where the bucket is predominately filled with water). While this is not bucket decanting per say, a bucket filled predominately with water (when thin lifts are taken) will result in water seeping from the buckets and with it the suspended matter associated with it would also flow downstream.

GE's field attempts to measure the impact of the bucket decant water do not yield useful estimates in light of the confounding factors that affected these attempts. However, the sensitivity analyses presented above do suggest that the overall impact of the bucket decanting can be quite significant regardless of the vector of the PCB release.

4.6 Effectiveness of Resuspension Controls

Because of the likelihood for sediment resuspension during the various in-river activities that were implemented during Phase 1, including: removing debris, dredging, backfilling, capping, moving and anchoring barges and work boats, etc., resuspension control measures were assessed during remedial design. Some of the fine sand, silt, and clay particles disturbed during operations may remain in suspension and move downstream, causing increases in concentrations of PCBs and/or total suspended solids. Analysis during pre-design indicated the need for contingency controls in the east channel at Rogers Island and in EGIA to reduce sediment resuspension and transport.

Two contingency resuspension control measures were implemented in Phase 1. First, a rock dike was installed at the northern end of the eastern channel of Rogers Island, and silt curtains were installed at the southern end of Rogers Island. The rock dike was designed to reduce the flow of water through this portion of the river (by diversion of flow to the west channel); the silt curtain was designed to reduce the downstream transport of resuspended sediments, and also to control access to this section of the river for safety purposes. Resuspension control was also implemented at CU18 near Griffin Island, where both rigid (sheet pile) and flexible (silt curtain) containment systems were installed in an attempt to reduce downstream transport of TSS and PCBs.

The rock dike setting is unique to Phase 1 and not applicable to Phase 2 dredging. The implementation of the rock dike reduced the flows in the east channel as intended, but also increased the flows and velocities and loads in the west channel. Under normal conditions the flow through the west channel is 65 percent of the flow in the river. With the rock dike in place, 96 percent of the flow went through the west channel.

The release of PCBs in the east channel was influenced by NAPL, dissolved PCBs, uncertainties in the measured depth of contamination (DoC) used to design the dredging cut lines, and debris. Although TSS concentrations measured by the monitoring buoy within the silt curtain containment were significantly higher than concentrations in the upstream buoy, the silt curtain was completely ineffective in containing the PCBs. The relatively quiescent conditions in the east channel resulted in highly variable concentrations with values ranging from several hundred to greater than 5000 ng/L during transect studies. The frequent presence of NAPL in the east channel likely played a role in elevating water column concentrations and load from this section of the river. GE collected transects that yielded highly variable results and estimated an average load of 1 kg/day from the east channel. Using these "snapshot" measurements and instantaneous loads to estimate the load from the east channel is questionable given the complex hydrodynamics of the river after installation of the rock dike. Due to water level fluctuations, there are times when flow reversals occurred in the east channel, and thus the net output is likely lower than estimated. The fraction of this PCB that is effectively transported to Thompson Island is unknown.

In the East Griffin Island Area, water sampling conducted within the sheet piling found total PCB concentrations that ranged from 21,000 to over 32,000 ng/L, or approximately two orders of magnitude higher than those found within the adjacent river during the transect studies (see Section 4.2). PCBs within the sheet pile area were predominantly in the dissolved phase, and these caused high PCB volatilization that resulted in downwind exceedances of the PCB Air Performance Standard. There were also reports of the development of hypoxia in the sheet-piled area and mortality of some fish trapped inside the area (approximately 6 fish were involved in the fish kill). The sheet piling in this area effectively controlled the downstream transport of suspended sediments. However, the PCB load released from the sheet pile area cannot be established from the limited transect data because the poor sample collection sequences and highly variable results, as well as the occurrence of other activates outside the sheet piling that could produce PCB loads. For example, several transects were coincident with dredging in CU-17 immediately upstream, or with resuspension induced by boat traffic, as the boat basin was located just south of this area. During August 10, 12, 14, and 17, 2009, the differences in instantaneous Total PCB loads between upstream and downstream transects in EGIA were 1.9, 0.9, -3.8, and 4.0 mg/sec. The high variability and negative load gain suggest that the downstream impact of the PCB losses from the sheet piling is likely within the noise of the data, and therefore the load contributed by the sheet pile area cannot be discerned.

The major reason for the difficulty in controlling PCB transport was the role of dissolved phase release and the impact of PCBs in NAPL. While dredging-related solids control was quite successful, PCBs were routinely released by remediation-related activities. The data obtained on the rock dike and the sheet pile areas do not demonstrate their effectiveness but nor do they show them to be ineffectual.

5 SUMMARY OF PHASE 1 RESUSPENSION OBSERVATIONS AND RECOMMENDATION FOR REVISION OF STANDARDS FOR PHASE 2

General Electric Company (GE) conducted Phase 1 of the Hudson River dredging project during 2009 pursuant to the 2006 Consent Decree with EPA. The design goal for Phase 1 was to dredge, dewater, and dispose of approximately 265,000 cubic yards (cy) of sediment from 18 sediment CUs located within the Northern Thompson Island Pool (NTIP) and East Griffin Island

Area (EGIA) of the upper Hudson River. This section summarizes the performance of Phase 1 dredging in relation to compliance with the Resuspension Standard. In addition, recommendations for Phase 2 of the project are proposed.

5.1 Summary of Observations

5.1.1 Near-Field Water Column Concentrations

- There was no significant transport of solids during dredging beyond the immediate vicinity of the dredging operation as indicated by the TSS data.
- Average TSS concentrations in the near field were well below the evaluation criteria of 100 mg/L at 300m and 700 mg/L at 100 m downstream of the dredging operations, respectively. There were four cases were high TSS beyond the 100 mg/L criteria were observed, but these high TSS results were not supported by the continuous turbidity measurements.
- Median differences in TSS concentrations between the downstream buoys and corresponding upstream buoys were less than 5 mg/L in all cases. This difference, while small, was systematic and statistically significant.
- In West Rogers Island, TSS concentrations in downstream buoys, relative to their upstream counterparts, tended to be more variable after late September, probably reflecting the effect of backfilling of CUs.
- Turbidity was not a reliable surrogate for TSS concentrations observed in daily transect samples.

5.1.2 Far-Field Water Column and Fish Concentrations

- Water column PCB concentrations at Thompson Island, Lock 5, Stillwater and Waterford were significantly above baseline concentrations during dredging. Some of the factors that affected the water column concentrations during dredging include, but are not limited to: the release of PCB contaminated oil sheens during dredging, dredging related sediment spillage, vessel traffic, dredge bucket decanting into the river, spillage from partially closed dredge buckets, the number of bucket interactions with the sediment, and sediment removal rates.
- The federal drinking water maximum contaminant level (MCL) of 500 ng/L was exceeded three times during the course of the project at Thompson Island, which resulted in the suspension or alteration of dredging operations. Exceedances occurred on August 6 – 8, September 10, and October 13.

- The action level of 350 ng/L, which is specified as a seven-day flow-weighted average, provided the intended warning during the first exceedance of the Resuspension Standard on August 6-8 at Thompson Island. An engineering evaluation conducted to determine why the Standard was exceeded indicated the presence of significant dissolved phase PCBs in the water column. This evaluation did not look at possible resuspension inputs such as dredging technique, number of bucket bites, or the impact of vessel traffic.

- There was significant variability in the PCB concentrations reported for some replicate samples. This variability, in part, may likely be due to the non-homogenous nature of the NAPL reported during dredging. Samples of the oil sheens collected and analyzed show significantly higher PCBs, but replicate results of the oils sheen samples varied by more than an order of magnitude in some cases. This measurement variability is the likely cause of the high variability in TPCB concentrations observed in duplicate samples collected at Thompson Island. It was also likely responsible for a peak concentration at Lock 5 greater than the Resuspension Standard on October 26th, which the replicate analysis failed to confirm.

- Incidences of high vessel traffic/barge disturbance were observed to significantly affect water column PCB concentrations in the far-field. Spikes in TPCB concentrations were observed when a barge was grounded around May 18th, and when a boat accident occurred on November 17th. Boat distance travelled on Sundays when no dredging occurred were correlated to PCB concentration at Thompson Island.

- The impact of dredging cannot be predicted by mass removed and river flow/velocity alone. Statistical analysis indicate that several processes may be contributing to the PCB transport to the far-field at Thompson Island The most likely factors contributing PCBs to the water column are not unexpected—mass and volume removal, vessel traffic, disturbance of exposed contaminated surface sediments, processes associated with backfilling, and the extent to which dredge buckets may be overly full or dredging is hurried.

- The increases in fish tissue PCB levels were predominantly identified in the Thompson Island Pool (i.e., the section of the river where the Phase 1 dredging occurred), with limited evidence of responses downstream.

- Spillage from partially-closed dredge buckets (where debris interfered with bucket closure). Both suspended solids and interstitial fluids could be released in this manner.

- Debris removal to address smaller obstruction was inefficient. Debris removal took place at the beginning of the operation to remove large objects identified on the river bottom. However, subsequent debris removal attempts did not remove substantive amounts of debris but did serve to disturb and resuspend sediment.

- Non productive clean-up passes (fine grading of the sediment surface to meet close dredging tolerances), likely contributed to resuspension with little net sediment removal.

- Water column concentrations of PCB decreased downstream of Thompson Island to Waterford. This decrease in PCB concentrations cannot be explained by settling of solids from the water column. Since dredging activities ended, water column concentrations have returned to baseline levels at all far-field stations.

- There were no observable impacts of dredging to the water column concentrations downstream of Waterford.

5.1.3 Far-Field PCBs Loads and Export rate

- The TPCB and Tri+ PCB 7-day running average net loadings at Thompson Island exceeded the Phase 1 Control Levels of 1,080 g/day and 361 g/day, respectively, for the majority of the dredging period. After October 27th, the daily average TPCB load at Thompson Island decreased, but estimates were still above the evaluation criteria of 540 g/d, as dredging related activities continued until November 27th.

- TPCB Loads at Lock 5 and Waterford were significantly lower than loads at Thompson Island. At Waterford, the 7-day average load was less than the Evaluation Level about 50 percent of the time and exceeded the Control Level 20 percent of the time.

- Although PCB daily loads decreased down river significantly, a concurrent decrease was not observed in solids transport. Therefore, PCB transport was probably not controlled by solids transport, especially given the significance of non-particulate PCB in the near-field. It is likely that other mechanisms, including volatilization and dilution, controlled the transport of PCB downriver.

- The resuspension goal of maintaining the TPCB export rate to 1 percent or less relative to the mass of PCBs removed was achieved, particularly at Waterford, when productivity reached higher levels after the start of dredging.

- The Resuspension Standard performance targets for cumulative load for both TPCB (117 kg) and Tri+ PCB (39 kg) were exceeded at all of the downstream monitoring stations. Between May 15 and November 27th, the cumulative TPCB load at Thompson Island of 436 kg is approximately 1.5 times higher than the load at Lock 5 and about 3 to 4 times higher than the export to the Lower Hudson as measured at Waterford. The load at Thompson Island was still small relative to the overall mass removed in Phase 1, 436 kgs, vs the 20,000 kgs removed (roughly 2 percent).

- Baseline loads prior to the onset of the Phase 1 dredging indicate a much slower rate of recovery for the Upper Hudson than forecast by the modeling analysis prepared for the 2002 ROD. Specifically, baseline loads from the Upper to the Lower Hudson are currently 2 to 3 times greater than forecast. Since the remedy is expected to substantively reduce these loads, the magnitude of the MNA loads further supports raising the allowable short-term dredging-related loads to the Lower Hudson, reflecting the anticipated dredging losses from the current estimates of PCB inventory.

- An initial analysis of the loads under MNA , the remediation and the post-remedial period (included with this report an appendix) show that there is little long-term impact of dredging-related loads, given that these loads will be offset by future reductions in loads to the Lower Hudson due to the remediation. The analysis was conducted based on a loss rate of roughly 1 percent of the current inventory estimate, indicating that as much as 2,000 kg may be released to the Lower Hudson with little or no long term impacts.

- Bathymetric measurements collected in 2001, 2005 and 2009 of the Phase 1 CUs document the movement of large masses of PCB-contaminated sediment from the river bottom. This volume (roughly 35,000 cubic yards for the ten CUs dredged), at about 75 mg/kg TPCBs, represents a transport of PCB mass almost 4 times greater than the mass losses attributable to dredging in Phase 1. It is expected that similar sediment movements in other areas of the Thompson Island Pool (Phase 1 addressed only 50 acres of the 500 acre Pool) would result in mass transport significantly greater than the mass releases due to the entire Phase 2 sediment remediation.

5.1.4 Special Studies Observations

- PCB release in the vicinity of dredging operations was dominated by lighter congeners predominantly in the dissolved and NAPL phases. As the water column content was transported to Thompson Island, the lighter fractions were lost, probably through volatilization.

- The sediment traps and accompanying coring program failed to confirm that any important re-contamination occurred in non-target areas during dredging. The analysis of the post-dredging coring results shows that redeposition of PCB contaminated sediments within the CUs themselves does not blanket the entire CU, despite being at the center of dredging-related resuspension. Thus settling of PCB contaminated sediment is considered a minor contribution that may affect areas proximal to the operations but is unlikely to affect broad areas of the river bottom.

- Decanting of water from dredge buckets directly into the river is not a best management practice. Water contained with the sediment was extensively allowed to drain back to the river, potentially releasing interstitial dissolved PCBs as well as interstitial PCB-bearing oils.

5.2 Recommendations for Phase 2

The Resuspension Standard provided guidance for possible revision of the Standards for Phase 2. The recommended revisions for Phase 2 are as follows:

5.2.1 Considerations for Setting a Revised Load Standard

The analysis presented in Section 3.3.9 and Appendix I-G describe a scenario wherein roughly 1 percent of the current PCB mass of contaminated sediments slated for remediation is lost to the Lower Hudson River. The cumulative loads under this scenario are contrasted with those delivered under MNA. The result of this comparison indicates that a dredging-related load of this magnitude will be offset by the ensuing reduction in MNA loads with no long term impacts to the Lower Hudson. This load analysis yields a much higher load criterion to the Lower Hudson than in the original Resuspension Standard and reflects the significantly greater MNA loads and Upper Hudson PCB inventory than were estimated when the standards were first developed.

While EPA proposes to set the acceptable dredging-related loss to the Lower Hudson at roughly 2,000 kg at Waterford for the duration of the project, the proration of this load over time and to the upper river monitoring locations is still under development. EPA expects to complete this analysis in April 2010 and will at that time provide its conclusions in the form of an addendum to this report. The proration will consider a number of concerns, based in large part on the observations of Phase 1. These include:

- The observed 3-fold decline in dredging-related PCB load from Thompson Island to Waterford. This decline provides a basis to allow upstream stations to have greater PCB loads relative to Waterford.
- The distribution of the PCB inventory for remediation in the Upper Hudson. More than 80 percent of the inventory is located upstream of the Schuylerville station.
- The goal of minimizing exceedances of the 500 ng/L water column standard in the Upper Hudson.

- Reduction to the extent possible of dredging-related loads based on future improvements to the dredging operations. As described in Appendix I-G, EPA is currently developing a model relating various dredging parameters to far-field water column concentrations. The recommendations from the model analysis as well as other recommendations in this report should serve to measurably reduce the rate of PCB loss.

5.2.2 Standards and Monitoring

- EPA will adjust the seasonal load and corresponding Evaluation and Control Level loads upwards, in accordance with new information on the inventory of PCB targeted for removal. At a minimum, the current load targets will be tripled. The far-field load limit should be applied to the Waterford station, and only used as a guide at the other stations.

- As dredging proceeds downriver, an automated water sampling station should be constructed at Stillwater to allow for collection of 24-hr composite samples. Faster turnaround times for these downstream far-field stations will be required as dredging proceeds downstream.

- Reduce the near-field evaluation levels as follows:

    - A net increase in TSS concentration of 50 mg/L above ambient (upstream) conditions at a location 300 m downstream of the dredging operation or 150 m downstream from any suspended solids control measure (*e.g.,* silt curtain).

    - The sustained TSS concentration of 100 mg/L above ambient (upstream) conditions at near-field stations located to the side of dredging operations or the 100 m downstream of dredging operations.

- The water column Control Level of 350 ng/L should be maintained and used to provide warning for increased concentrations and a guide for reviewing of the dredging process.

- The 500 ng/L threshold will also be maintained. At Thompson Island this threshold should be used as a trigger to require operational changes, but not necessarily an operational shutdown, at EPA's discretion.

- The near-field buoy deployment may be reduced for Phase 2, especially after the first month of dredging if the far-field solids concentrations are similar to levels observed during Phase 1. However, if after the reductions in near-field monitoring, higher sustained solids concentrations are observed at the far-field, a mechanism for implementing near-field investigation should be included in the revised program.

- The seven day averaging period for daily loads should be maintained.

5.2.3 Operational Controls Affecting Resuspension

- A proactive approach is needed to control and collect PCB contaminated NAPL during dredging. Further evaluation assessing the effectiveness of various absorbents in capturing these sheens is recommended. The selected control should be placed around each dredge, or, alternatively, at the end of a string of CUs.
- Decanting of water during dredging should be eliminated to reduce the release of dissolved phase into the water column. Reduced bucket swing time should be considered.
- Silt-curtain barriers with potential for adsorption should be researched and bottom anchoring implemented when containment is required. Silt curtain barriers were installed in Phase 1 but not anchored at their bottoms. Anchoring the silt curtains may slightly impact productivity but is expected to enhance the project's ability to comply with the Resuspension Standard
- Project related vessels and tugs movement during should be minimized during dredging, especially in shallow areas where the potential to stir up sediments is high.
- Debris removal should be limited to a pass for large objects. Subsequent debris passes yielded little debris but disturbed the sediment and should be avoided.

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CHAPTER II
EVALUATION OF THE RESIDUALS STANDARD IMPLEMENTATION

CHAPTER II

Evaluation of the Residuals Standard Implementation

CHAPTER II SUMMARY

The Residuals Standard consists of procedures for managing residual sediment contamination following the removal of the entire contaminated sediment inventory at a particular dredging area, or Certification Unit (CU). The Residuals Standard includes the implementation of a post-dredging sampling and analysis program to quantify PCB concentrations in residual sediments and a set of required actions based on the detected concentrations. In brief, the Residuals Standard requires the collection and analysis of 40 sediment cores from each CU following the removal of sediments to the design cut line. The sediment cores are divided into 6-inch segments. The 0-6 inch segment is analyzed immediately for PCBs, and deeper segments are archived should additional data at depth be needed to design subsequent dredging passes. Based on the sediment analytical results and the number of prior dredging passes conducted, a particular CU may be closed with backfill, re-dredged, evaluated in concert with other nearby CUs, or closed with an engineered cap.

The use of Phase 1 data to evaluate the Residuals Standard's effectiveness is challenging because the majority of the dredging passes conducted in the CUs were removing inventory that was not adequately characterized prior to design and not a true, post-dredging residual. The Phase 1 design cut lines were set too shallow in general; many times even post-dredging cores did not fully penetrate the depth of the contaminant inventory. In CU-1, post dredging cores did not penetrate the depth of the contaminant inventory until the final dredging cut was made, and then only after construction of 3-ft deep test pits. Therefore, the data from these cores were not strictly pertinent to the criteria in the Residuals Standard, which were developed to characterize and manage an anticipated dredging residual approximately 0-6 inches in thickness overlying uncontaminated sediments with Tri+ PCB concentrations less than 1 ppm. It is concluded from the Phase 1 data that the Residuals Standard can be appropriately implemented and readily achieved during Phase 2 if the depth of contamination (DoC) is better characterized and appropriate overcut intervals are added to address uncertainties in the design cut lines.

While the mechanical dredge proved successful in most areas of Phase 1, additional equipment should be available to the dredging team for removing inventory composed of wood debris. Where debris from wood processing operations is encountered, dredging should continue without further surveying and sampling until the debris has been removed and the underlying sediments are reached. This debris-bearing material was found during Phase 1 to be extensively PCB-contaminated and should be entirely removed where encountered during Phase 2. In addition, to address uncertainties in the DoC, the design cut line should be adjusted to include specific overcuts for inventory removal and residuals removal, regardless of coring methods used to define DoC.

To reflect the lessons learned during Phase 1, the Residuals Standard should be simplified for Phase 2 to reduce the number of response options to the 4 conditions generally encountered during interpretation of and response to the Phase 1 post-dredging sediment data.

Finally, many of the estimates of *in situ* PCB mass made by EPA for individual CUs and dredging passes to assess the application of the Residual Standard were also constructed by GE. For some parameters, such as volume removed, EPA and GE results agree well but for many others, particularly PCB mass, the results do not agree well and reflect significant differences in the numerical techniques used to estimate *in situ* PCB concentrations and sediment densities. This issue is addressed at various points throughout the chapter.

Summary of Detailed Conclusions

This section summarizes the major observations and conclusions from application of the Residuals Standard in Phase 1. Prior to beginning this summary discussion, it is helpful to review the original goals and objectives of the Residuals Standard.

As extensively described in the original documents (USEPA, 2004), the Residuals Standard was "*designed to detect and manage contaminated sediments that may remain after initial dredging in the Upper Hudson River…,*" anticipating "*…a residual of approximately 1 mg/kg Tri+ PCBs prior to backfilling.*" As also described in the original documents (USEPA, 2004), the objectives of the Residuals Standard were:

- *Affirmation of the removal of all PCB-contaminated sediment inventory in target dredging areas* (emphasis added).
- *An arithmetic average Tri+ PCBs concentration in the residual sediments of < 1 mg/kg.*

These objectives were intended to satisfy the intentions of the ROD, specifically, the expectation of "*removal of all PCB-contaminated sediments in areas targeted for remediation.*"

Various forms of residual sediments were identified in the Residuals Standard (USEPA, 2004), including:

- *Contaminated sediments that were disturbed but escaped capture by the dredge.*

- *Resuspended sediments that were redeposited (settled).*
- *Contaminated sediments remaining below the design dredging cut elevations (e.g., due to uncertainties associated with interpolation between pre-design sampling nodes or insufficient core recovery).*

A review of the objectives of the Residuals Standard in light of observations collected during the Phase 1 program indicates the following successes were achieved:

- The PCB sediment inventory in the Phase 1 CUs was reduced by 98 percent, excluding CU-1, meeting the goal of the ROD for 96-98 percent removal. This accomplishment is largely due to the post-dredging sampling requirements in the Residuals Standard.
- The Phase 1 sediment removal volume was approximately twice the adjusted volume in the Phase 1 design (after accounting for setbacks and bathymetric changes). The presence of substantial thicknesses of inventory found in some areas during Phase 1 after the initial dredging pass far exceeded the amounts of 'missed inventory' anticipated during development of the Residuals Standard. While a comparatively thin layer of un-dredged material can be considered residual sediment, more than 6 inches and up to 13 feet of additional sediment requiring dredging can be defined only as missed contaminated sediment inventory.
- Surface sediment PCB concentrations were greatly reduced prior to backfilling or capping of the CUs.
- Phase 1 removed more PCB mass and sediment volume than called for in the ROD, even though 8 CUs were not addressed. This was the result of the substantial increase in the actual CU inventories as well as the selection of the CUs with the greater PCB inventories from the original planned 18. Tri+ PCB concentrations in more than 2/3 of all post-dredging coring locations (and by inference 2/3 of CU surface area) were reduced to a local average of 1 mg/kg.
- Cap placement largely addressed residual sediment contamination (less than 6 inches thick), and not inventory (greater than 6 inches of contaminated sediment). Excluding CU-1, only 16 percent of the capped post-dredging sampling nodes (representing about 2.3 acres) had contamination extending deeper than 6 inches.
- Despite the underestimated DoC and inaccurate dredging cut lines, three dredging passes were adequate to get most CUs close to compliance.
- After three dredging passes, the average number of non-compliant sampling nodes was 14 percent of the total nodes for each CU (about 7 nodes per CU), excluding CU-1.

The extensive data set collected during Phase 1 provided information on many aspects of post-dredging sediment contamination and the accuracy of the original dredging design cut lines. The major observations and conclusions that stem from these data are outlined below. These observations form the basis for the proposed revisions to the Residuals Standard described in Section II-6.0.

- The impact of the poorly defined DoC resulted in removing only 49% of the actual inventory by volume and only 58% of actual inventory by mass in the 1st dredge pass.
- The original design cut line elevation was an underestimate of the actual DoC surface on a CU-wide basis.
- Generally, the final removal volume per CU was 1.5 times the original design volume.
- The final removal volume per CU was generally 1.9 times the adjusted volume after the design was corrected for setbacks around obstructions and changes in bathymetry, meaning most CU removals went to a mean depth nearly two times the original mean DoC, although not all locations were doubled in depth.
- The final dredging depth was more than 6 inches beyond the original design surface (*i.e.,* equivalent to more than a 6-inch overcut) for nearly 70 percent of the original Sediment Sampling and Analysis Program (SSAP) locations. Of the remaining 30 percent, only 16 percent (about half of the 30 percent) had a final dredging depth within ± 3 inches of the original design cut lines.
- The final dredging depth was greater than 12 inches beyond the original design cut lines for 55 percent of the SSAP locations.
- Relative to the actual DoC reported for each core (as opposed to the locally interpolated design surface), the final depth of removal was more than 6 inches deeper than the core-based DoC (*i.e.,* more than a 6-inch cut beyond the core's DoC) for about 55 percent of the original SSAP locations. Similarly, the final depth of removal was greater than 12 inches deeper than the core-based DoC for about 45 percent of the SSAP locations. Of the 45 percent of locations that had less than 6 inches of additional dredging, 15 percent (about one third) were within ± 3 inches of the original core DoC.
- The confidence level of the SSAP cores (referred to as "core quality") was not a good predictor for the amount of additional dredging needed. Complete core locations (cores with a directly measurable DoC and labeled "1A"cores) required more than 6 inches of removal beyond the design cut lines 65 percent of the time. Incomplete (or extrapolated cores) with only an estimated DoC had more than 6 inches of removal beyond the design cut lines about 75 percent of the time.
- By river area, the east channel of Rogers Island had the greatest frequency of additional dredging by more than 6 inches (roughly 80 percent of SSAP locations), followed by the west channel of Rogers Island (roughly 70 percent of SSAP locations) and the East Griffin Island area (roughly 40 percent). The frequency of occurrence of dredging greater than 12 inches deeper than the design cut lines showed a similar trend.
- The Total PCB mass removed (20,000 kg) is roughly 1.5 times the original inventory estimate of 13,000 kg for the CUs dredged in Phase 1. After adjusting the original mass for

setbacks around obstructions and changes in bathymetry, the total PCB mass removed (20,000 kg) is roughly 1.8 times the adjusted inventory estimate of 11,400 kg.

- PCB-contaminated wood debris is present throughout the river and was observed in essentially all Phase 1 CUs. CUs at the northern end of the Thompson Island Pool had more debris than those in the southern end of the Pool, but it is anticipated that wood debris would be found throughout the Pool in the Phase 2 areas.
- The viability of "fine grading" (*i.e.,* dredging in thin lifts of 3 in or less, or to an assigned DoC line without an overcut, GE letter to EPA, 2009) was not borne out by the large number of dredging passes. The high degree of variability in the actual DoC surface precludes this approach to dredging. The dredging contractor spent much time trying to meet the initial design cut line (which proved to be an underestimate of DoC) to the required tolerance of ±3 inches. It would have been more efficient and productive to require a 9-inch overcut in addition to the design cut line with a relaxation of the tolerances to speed the dredging and closure of the CUs.
- Vibracoring proved to be unreliable for DoC determination under all conditions. In particular, the presence of woody debris in nearly all CUs prevented measurement of the DoC (by causing vibracore refusal) in at least some area of each CU until dredging removed the debris and coring could penetrate to underlying clean sediment.
- The lack of DoC characterization via each post-dredging coring round resulted in uncertainties in defining the next dredging pass that ultimately limited the ability to remove all inventory in 2 passes. Since post-dredging cores were analyzed incrementally (beginning with only the top 0-6 inch segment) after each dredging pass, the magnitude of the underestimate of DoC could not be rapidly identified and proactively addressed.
- Some capping took place because of the navigation schedule (*e.g.,* CUs 1, 4, and 8) and not because residual sediment contamination was inaccessible (*e.g.,* CUs 5 and 6).
- Capping covered 36 percent of the original Phase 1 areas. Excluding the CUs associated with the debris-laden navigation channel on the east side of Rogers Island as atypical, capping occurred in just 19 percent of the remaining CU areas.
- Much of the capping that occurred in CUs 5, 6, 7 and 8 was eventually covered by several feet of additional backfill as part of habitat restoration in these areas. As a result, these capped areas do not represent a significant loss of river bottom habitat due to sediment type change.
- The DoC in the navigation channel areas is at least the original canal design elevation (*i.e.,* low water surface elevation minus 14 ft), unless bedrock is encountered.
- Dredging passes were rapidly completed once decanting and "fine grading" (time spent cleaning the surface to meet the ±3 inch design tolerance) were limited, based on the faster dredging pass times achieved later in the Phase 1 project.
- The calculation process to identify nodes for re-dredging would sometimes result in nodes identified as compliant (*i.e.*, not requiring dredging) that were later found to be non-

compliant and required either dredging in a subsequent dredging pass or in some cases capping.

- EPA review of CU certification materials and decisions were typically conducted immediately upon delivery during daily 4:00 PM meetings with GE. Occasionally, additional review time was necessary, but these reviews were completed within 24 hours, thus resulting in no real impact to the dredging schedule.

For many post-dredging cores, only the top 6-inch segments were analyzed, consistent with the Phase 1 Residuals Standard but missing an opportunity to re-characterize the DoC where multiple dredging passes had already indicated that the DoC was not well-known. In cases where post-dredging cores indicate non-compliant levels of PCB contamination with respect to the standard, the use of the data to re-characterize DoC, in addition to characterizing the surface concentration after the initial dredging pass to meet the design cut line, is essential, as borne out by the Phase 1 experience with incomplete post-dredging cores.

For Phase 2 post-dredging cores, a minimum 2-foot sediment column (or to the depth of uncontaminated material as defined below, if shallower) should be analyzed as individual 6-inch segments to verify that detected PCBs are associated only with a true residuals layer and not underlying inventory. In this document, the phrase "uncontaminated" will be used to describe a sediment stratum that pre-dates and underlies the PCB-contaminated sediment. In some cases, the uncontaminated stratum may have distinct geologic properties from the contaminated sediment, such as bedrock or clay. To date the only sediment type that is known to represent uncontaminated material <u>and</u> is visually distinct is glacial Lake Albany clay. Thus this is the only material that can serve to reduce the sampling requirements for a core for the start of Phase 2. Other materials, if identified and tested, may be added to the list after sufficient Phase 2 experience. In all cases, the DoC must be well-defined by a minimum of two contiguous 6-inch core segments below 1.0 ppm Total PCB at all post-dredging sampling nodes prior to initiation of the next dredging pass. Also, the experiences gained from Phase 1 and the previous design sampling investigations show that vibracore collection is not consistently a reliable method to obtain cores for DoC determination due to refusal caused by the presence of woody debris in the subsurface.

1. PHASE 1 RESIDUALS MONITORING DATA

1.1 Overview of the Phase 1 Residuals Standard

The Residuals Standard is described in Volume 1 of the Engineering Performance Standards (USEPA, 2004) with additional supporting information provided in Volume 3 of the Standards. The Residuals Standard is briefly summarized below. The Fundamental Principles for the Development of the Residual Standard appear on page 26 of Volume 1. This text outlines the required processes and procedures for dealing with residual sediment contamination identified after a dredging pass. During the design of the Phase 1 remedy, minor revisions were made to the required actions defined by the Residuals Standard by way of the Consent Decree (USDC, March 23, 2006). These new criteria mainly dealt with two issues. The first issue dealt with considerations on the number of dredging passes required before closure of a particular CU. The second dealt with how contamination in shoreline areas would be dealt with during dredging and how shoreline stability would be handled post- dredging (described in further detail in Section II-5.3.3 and Chapter III Productivity Standard Section II- 2.2.5). The latter modification of the Standard was agreed to as part of the Critical Design Elements (CDE) attachment to the Consent Decree and is also presented by GE in the Performance Standards Compliance Plan (PSCP) (GE, March, 2009). Inventory can be defined as the "PCB mass in sediment deposits requiring removal to meet the ROD's objectives", (USEPA, 2004, Vol. 3, p 35). Dredging related residuals can be defined as sediments that escaped the dredge during removal and resettled or re-deposited. The practical definition of inventory for the purposes of the standard is the entirety of the contaminated sediment above the 1 mg/kg Total PCBs isocontour. The phrase 'missed inventory' is often used in this document to describe contaminated sediment not captured by initial dredging to the design cut lines or during subsequent dredging passes. Depending on the accuracy of the design removal surface (or "cut lines"), undisturbed sediment inventory as well as residual sediments may obtained while sampling an area after dredging.

1.1.1 Statement of the Residuals Standard

The Residuals Standard requires the implementation of a post-dredging sampling and analysis program to detect and characterize PCB concentrations in the residual sediments. The post-dredging sediment data are compared to the anticipated pre-backfill residual concentration of approximately 1 mg/kg Tri+ PCBs stated in the ROD, and a group of statistical action levels developed for the Residuals Standard. The approach to manage the residual sediments, including additional dredging, is then selected based on the statistical analyses of the post-dredging data (USEPA, 2004).

Management of residuals sediments is not considered complete until areas meeting the ROD criteria have been backfilled and areas that do not meet those criteria have been re-dredged and backfilled or capped as described in Section II-1.1.4.

1.1.2 Objectives

The Residuals Performance Standard was designed "to detect and manage contaminated sediments that may remain after initial remedial dredging" (USEPA, 2004, Vol. 1, p. 9). The objectives of the Residuals Standard, as stated in Volume 1, p. 53 (USEPA, 2004), are as follows:

- Affirmation of the removal of all PCB-contaminated sediment inventory in target dredging areas.
- An arithmetic average Tri+ PCB concentration in the residual sediments of ≤ 1 mg/kg.

To evaluate achievement of these goals, a series of statistical action levels was developed based on data from case studies. Case studies used were characterized by conditions (*e.g.*, freshwater, unidirectional flow) and remedial operations (*e.g.*, dredging in "the wet" rather than "in the dry" using newer technology) similar to those anticipated for the Hudson River remedial action.

1.1.3 Implementation of the Residuals Standard

As part of the Phase 1 Final Design Report, a set of 18 five-acre "certification units" (CUs) were identified for remediation in Phase 1. For each of these CUs, EPA and GE also developed a post-dredging sampling program, including a planned sampling grid. The results of each round of post-dredging sampling were then evaluated according to the numerical criteria provided in the Residuals Standard (USEPA, 2004).

Consistent with the Residuals Standard, each CU was sampled for compliance after each dredging pass was completed so that the appropriate action could be selected as the project progressed. In each five-acre CU, sediment cores were collected from 40 locations, evenly distributed across the CU. Initially, the 0-to-6 inch depth interval from each core was analyzed for Total and Tri+ PCBs. Deeper sections were initially archived for possible later analysis during the CU review process. The following values were derived from the analytical data obtained:

- Tri+ PCB concentrations in all 40 individual sediment samples within each 5-acre certification unit.
- Mean (*i.e.*, arithmetic average) Tri+ PCB concentration of the certification unit.
- Median Tri+ PCB concentration of the certification unit.
- The total PCB concentration from cores located in close proximity to the shoreline where depth of cut had to be limited due to shoreline bank stability concerns.

The action levels used to evaluate residual sediments (in addition to the ROD criterion to reduce contamination below 1 mg/kg Total PCBs) consist of two upper confidence limits (UCLs) and two prediction limits (PLs), as shown in Table II-1.1.3-1 .

The data from each core was compared to the Residuals Standard criteria, and assigned to one of the following categories:

- Compliant node – a core where the Tri+ PCB concentration in the top 6 inches maintains an average and median concentration of the CU that is less than or equal to 1 mg/kg and 6 mg/kg, respectively.
- Non-compliant node - the non-compliant node is a sample location whose sediments have Tri+ PCB concentrations in the top 6 inches that contribute to an average concentration of the CU greater than 1 mg/kg or median concentration of the CU greater than 6 mg/kg. Because not all the samples were cores (*i.e.,* some are grabs), the non-compliant node was defined further as:
    - Inventory node – a core whose sediments have Tri+ PCB concentrations that contribute to an average Tri+ PCB concentration greater than 1 mg/kg within a particular CU and contain sediments with Total PCB concentrations greater than 1 mg/kg below 6 inches.
    - Post-dredging >6 mg/kg node – a core or a grab sample where the Tri+ PCB concentration in the top 6 inches is greater than 6 mg/kg after the dredging pass.
    - Post-dredging ≤ 6 mg/kg node – a core or a grab sample where the Tri+ PCB concentration in the top 6 inches is less than or equal to 6 mg/kg.

The Residuals Standard also allowed comparison of a 20-acre joint evaluation area consisting of the CU under review and the three previously-dredged CUs within a two-mile stretch of the river. This allowance is applicable only for consecutive, non-capped CUs; however, this joint evaluation was never conducted during Phase 1, as there was only 1 CU where capping was not conducted.

1.1.4 Required Actions

The following responses [defined in Volume 3 of the Engineering Performance Standards (EPS) on p. 55] were required for Phase 1 of the dredging project based on the Tri+ PCB concentrations observed in the post-dredging samples collected after dredging individual CUs. Adjustments to these requirements based on the experiences of Phase 1 are suggested in Section II-6.0. In the original guidance found in the EPS, there was an important premise of a well-defined DoC as a precursor for successful CU dredging and implementation of the Residuals Standard. The Residuals Standard states (Section 2.3, p. 21) that "Appropriate selection of the cut lines will be an important factor in minimizing the number of re-dredging attempts." Specifically the guidance was predicated on the existence of a well-known DoC (based on design sampling), such that primarily residuals and a minimal amount of 'missed inventory' would require characterization via the post-dredging cores. As will be shown in Section II-2.0, this was generally not the case. In fact, essentially every dredging pass included some removal of contaminated sediment inventory (*i.e.*, removal of sediment below 6 inches of depth).

Per the Residuals Standard and the PSCP, up to 4 dredging passes were envisioned per CU. The first was, by definition, an inventory removal pass, potentially followed by a second inventory pass, if needed. These inventory passes were to then be followed by up to 2 residuals passes, intended to address surficial contamination (less than 6 inches thick) resulting from dredging disturbances or vestiges of contaminated sediment inventory. In actuality, contaminated sediments at thicknesses of 12 inches or more were identified for removal beneath at least some cores in nearly every round of dredging.

The responses listed below were developed as part of the original Residuals Standard and in the PSCP. Despite the developments listed above, all but Response 2 were applied in Phase 1 at the end of each dredging round as appropriate.

Response 1: Backfill (where appropriate) and demobilize at certification units with all of the following:

- An arithmetic average residual concentration less than or equal to 1 mg/kg Tri+ PCBs;
- No sediment sample result greater than or equal to 27 mg/kg Tri+ PCBs; and
- Not more than one sediment sample result greater than or equal to 15 mg/kg Tri+ PCBs.

The Residuals Standard also states that portions of a contiguous CU may be backfilled after the cut lines are met if:

- The area will not be re-contaminated;
- Dredging proceeds downstream in the certification unit;
- The Tri+ PCB arithmetic average concentration of the samples collected from the portion of the certification unit is 1 mg/kg or less; and
- All such nodes sampled are less than the lower of the two Prediction Limit (PL) action levels (15 mg/kg Tri+ PCBs).

The PSCP modifies these conditions as follows:

- Dredging proceeds in a downstream direction in the CU, and EPA has concurred on the Dredging Completion Approval Forms for all CUs that are upstream of the portion of the contiguous CU;
- The arithmetic average Tri+ PCB concentration of the samples collected from that portion of the CU is 1 mg/kg or less;
- All nodes sampled within that portion of the CU have Tri+ PCB concentrations less than 15 mg/kg; and
- GE has dredged a portion of the CU.

Response 2: Jointly evaluate a 20-acre area for a certification unit with all of the following:

- An arithmetic average residuals concentration greater than 1 mg/kg Tri+ PCBs and less than or equal to 3 mg/kg Tri+ PCBs;
- No sediment sample result greater than or equal to 27 mg/kg Tri+ PCBs; and
- Not more than one sediment sample result greater than or equal to 15 mg/kg Tri+ PCBs.

For the 20-acre evaluation, if the area-weighted arithmetic average of the individual means from the certification unit under evaluation and the three previously dredged certification units (within a two-mile stretch of the river) is less than or equal to 1 mg/kg Tri+ PCBs, backfill may be placed. In this case, subsequent testing of the backfill is required to confirm that its surface concentration is less than or equal to 0.25 mg/kg Tri+ PCBs. If the surface concentration does not meet this criterion, the backfill must be dredged, replaced, and retested or remedied via another method with input from EPA.

If the 20-acre evaluation does not yield a combined average of 1 mg/kg Tri+ PCBs or less, the certification unit must be re-dredged (see Response #4 below for actions required during and following re-dredging) or a subaqueous cap constructed. Re-dredging or capping is to be conducted at the specific areas within the certification unit that are causing the non-compliant mean concentration. If the certification unit does not comply with Response 1 or 2, above, after two dredging passes targeting a 0-6 inch layer only, capping may be implemented in lieu of further dredging attempts subject to EPA approval, as described in Response #5, below.

Response 3: Re-dredge or construct a subaqueous cap for a certification unit with all of the following:

- An arithmetic average residuals concentration greater than 3 mg/kg Tri+ PCBs but less than or equal to 6 mg/kg Tri+ PCBs;
- No single sediment sample result greater than or equal to 27 mg/kg Tri+ PCBs; and
- Not more than one sediment sample result greater than or equal to 15 mg/kg Tri+ PCBs.

Two options are provided to maintain flexibility and productivity (*e.g.*, some areas may not be conducive to further dredging). If re-dredging is chosen, the surface sediment of the re-dredged area must be sampled and the CU reevaluated. If the CU does not meet the requirements of Responses #1 or #2 following two dredging passes targeted on the removal of a 0-6 inch layer only, capping may be implemented in lieu of further dredging attempts, subject to EPA approval as described in #5, below.

Response 4: Re-dredging is required in any of the following cases:

- For areas of elevated Tri+ PCB concentrations within a certification unit with an arithmetic average residuals concentration greater than 6 mg/kg Tri+ PCBs;
- To address individual sampling point(s) with concentrations greater than or equal to 27 mg/kg Tri+ PCBs; or
- For instances of more than one sampling point with concentrations greater than or equal to 15 mg/kg Tri+ PCBs.

Sampling at depths greater than 6 inches will be triggered by an arithmetic average residual concentration of greater than 6 mg/kg Tri+ PCBs. The horizontal extent of the area requiring sampling at greater depth will be determined by the median Tri+ PCB concentration. If the median concentration in the certification unit is greater than 6 mg/kg Tri+ PCBs, collection and analysis of additional sediment samples is required from deeper intervals over the entire certification unit (*e.g.*, 6 to 12 inches, 12 to 18 inches, etc.) as necessary to re-characterize the vertical extent of PCB contamination (the DoC). If the median concentration is 6 mg/kg Tri+ PCBs or less, characterization of the vertical extent of contamination is required only in the areas within the certification unit that are contributing to the noncompliant mean concentration. Additional sampling to characterize DoC is required only once per certification unit.

The Residuals Standard provides a mechanism for calculating the horizontal extent of re-dredging. All re-dredging attempts are to be designed to reduce the mean Tri+ PCB concentration of the certification unit to 1 mg/kg Tri+ PCBs or less and to remediate any sampling nodes with Tri+ PCB concentration equal to or greater than 15 mg/kg. If after two re-dredging attempts, the arithmetic average Tri+ PCB concentration in the surface sediment still is greater than 1 mg/kg, then capping is to be implemented as stated in #5, below.

The PSCP goes on to state that the number of dredging passes conducted under this response is two per condition – *i.e.,* dredging of non-compliant nodes with Tri+ PCB concentrations greater than or equal to 15 mg/kg and dredging of nodes contributing to a CU-wide average greater than 6 mg/kg.

Response 5: Capping. At areas where two residual dredging attempts do not achieve compliance with the residuals criteria, as verified by EPA, construct an appropriately designed subaqueous cap, where conditions allow. As with #3, the following criteria are met for the area left uncapped:

- The arithmetic average of the nodes in the uncapped area within the CU is 1 mg/kg Tri+ PCBs or less; and
- No individual node 15 mg/kg Tri+ PCBs or greater.

The PSCP also states that for shoreline areas with 2-foot cuts, results from individual sample nodes will be compared to a level of 50 mg/kg Total PCBs. Where samples have Total PCB concentrations less than 50 mg/kg, GE may either perform additional dredging or place a cap over the area of those samples (at GE's election). However, if the overall data from the CU including the shoreline area meet the criteria allowing the placement of backfill without further response actions, the area will be backfilled.

In cases where a cap is placed within a shoreline area with a 2-foot cut, the PCB data from that area will not be included in the evaluation of the sampling data for the remainder of the CU. Further, in cases where a portion of such a shoreline area has been identified for capping, the remainder of the CU must achieve a Tri+ PCB average of less than or equal to 1 mg/kg (with no sampling node exceeding 15 mg/kg).

A flow chart illustrating implementation of the Residuals Standard is shown in Figure II-1.1.4-1. A second flow chart, Figure II-1.1.4-2 , illustrates the requirements in the event that a shoreline area subject to bank stability issues is identified in the CU.

1.1.5 Preference for Dredging

The selected remedy includes dredging of contaminated sediment, using PCB inventory and surface concentration as the primary means to target removal areas. While the Residuals Standard of approximately 1 mg/kg Tri+ PCBs prior to backfilling is achievable (based on review of case studies), it was recognized that residual concentrations may exceed the standard in a limited number of areas after the initial dredging attempt. It was anticipated that the non-compliant residuals would likely be associated with difficult-to-dredge bottom conditions such as bedrock outcrops and boulder fields. The capping contingency was added as an option to address this scenario. Capping performed under the Residuals Standard was not intended to sequester significant PCB inventory.

2. Evaluation of the Adequacy of Phase 1 Design Cut Lines to Address Full Contaminated Sediment Inventory

The Residuals Standard was developed with the expectation that the DoC would be properly defined by the SSAP cores and that the designed dredging cut lines would be sufficient to target existing PCB inventory for removal. The cut lines were also expected to include a 6-inch overcut to address uncertainty and thus minimize ‘missed’ inventory; however, GE did not agree to this measure and it was not incorporated into Phase 1. The post-dredging cores collected after the initial dredging pass would therefore be expected to detect contamination only in the top six inches (due to the expected presence of a comparatively thin layer of dredging residuals). In contrast, analyses of post-dredging core samples showed that in all CUs, PCB inventory (identified by greater than 6 inches of contamination) remained beneath the design cut lines, requiring additional dredging passes.

Most areas were dredged to depths greater than the design cut lines that were based on the initial DoC interpolated from the SSAP cores and as a result, a larger than expected sediment volume was removed. [The design cut line is not necessarily the same depth as the DoC determined in a SSAP core; the Phase 1 DAD (GE 2005) explains the difference between DoC and design depth of cut]. Figure II-2-1 is a bar graph showing the actual dredged volumes vs. original and adjusted design volumes by CU. Because a high percentage of SSAP cores were incomplete in all CUs except for CU-17 and CU-18, and because there was a significant discrepancy between design cut lines and the depth to which contamination was encountered during dredging, the relationships among SSAP core completion, predicted DoC based on SSAP cores, the dredging cut lines designed based on the predicted DoC, and the DoC actually encountered during dredging are evaluated and tested in this section. This was accomplished by examining SSAP core completion percentage in each CU, the uncertainty of DoC predictions using SSAP core data, the correlation between SSAP core completion and the reliability of DoC predictions, and other factors affecting DoC predictions.

Based on the analyses in this section, additional complete cores should be collected in Phase 2 areas that are under-characterized (have a large number of incomplete SSAP cores) to better predict DoC and refine the design cut lines. Core collection, whether during additional definition of the DoC or as a post-dredging assessment, needs to fully penetrate the contaminated sediment, with geologic indicators of uncontaminated material and/or two successive 1 mg/kg PCB core segments used to confirm the DoC at the core location.

Also, measures need to be taken during design and dredging to account for the uncertainty in the SSAP data predictions of DoC. The recommended solution is to provide a minimum 9-inch overcut in the design of dredging cut lines. Where many cores are incomplete, the dredging overcut may need to be increased to 18 inches.

Section II-2.0 presents data evaluations that confirm that design cut lines were set at depths too shallow to remove the contaminated sediment inventory:

- Final dredging depths were deeper than design cut lines in all CUs (II-2.1).
- Dredging volumes were 80 percent greater than estimated design volumes (II-2.2.)

Section II-2.0 also examines the root causes of the underestimates in the design cut lines:

- About 50% of the SSAP cores were incomplete and did not capture the DoC (II-2.3)
- In CUs with higher percentages of incomplete SSAP cores, the difference between the final dredging depth and the design cut lines was greater (II-2.4).
- Even in co-located pairs of SSAP cores, the measured DoC was highly variable, suggesting a design overcut is necessary to address uncertainty (II-2.5).
- Significant bathymetric changes were experienced in the Phase 1 CUs prior to dredging, creating additional uncertainty in DoC (II-2.6).
- Fluctuations in bathmetry prior to dredging contributed to the uncertainty in DoC (II-2.7).
- Discussions were held with GE during design regarding uncertainty in DoC and the potential shortcomings of DoC extrapolation from incomplete cores and interpolation between cores to develop cut lines (II-2.8).
- The incorporation of an overcut will help manage the uncertainty in DoC and hasten CU remediation without adverse impacts to the project (II-2.9).

2.1 Final Dredging Depths were Deeper than Design Cut Lines in Phase 1 CUs

Due to the presence of contaminated sediment inventory not identified during the SSAP effort, the final dredging depths are deeper than the design cut lines in portions of all 10 CUs dredged during Phase 1. For the majority of the CUs, the final dredging depth exceeded the design cut line by more than 1.5 feet on average. For CU-1, where the increase in dredging volume over the original estimate was the largest, the final dredging depth was deeper than the design cut line by approximately 6 feet on average for the complete extent of the CU. The maximum difference (deeper) between the final dredging depths and design cut lines in CU-1 was about 13 feet.

For CUs 2, 3, 4, 5, 7, and 8 the final dredging depth was deeper than the design cut line in all areas except where bedrock and clay were encountered. (In some areas, the final dredging depth was shallower than the design cut lines due to the the presence of underlying bedrock or clay.) In these CUs, the difference between final dredging depth and the design cut lines was variable, indicating that the DoC was not consistent across the CUs and deeper pockets of contamination were present in isolated places. For CUs 2, 3, 4, 5, 7, and 8, the average increase in the actual dredging depth ranged from 1.2 to 2.2 feet deeper than the design cut lines and the maximum increase ranged from 8 to 13 feet deeper than the design cut lines.

In CUs 17 and 18, the SSAP cores were more successful in characterizing the depth of contamination in some areas, and consequently the final dredging depth was within three inches of the design cut line for at least 25 percent of the CU extent. In the remaining 75 percent of these CUs, the average increase in final dredging depth vs. the design cut line depth was approximately one foot, with a maximum increase of approximately six feet.

For CU-6 the average increase in final dredging depth was approximately 0.7 feet; however, this is due to the fact that bedrock and or boulder fields were encountered in approximately 70 percent of CU-6. Rip-rap and bridge abutments were also observed in this CU in areas where bedrock was not encountered.

The average difference between final dredging depth and design cut lines are presented in Table II-2.1-1. Note that the statistics presented in this table do not include areas within the allowed rip-rap and structural offsets but include bucket refusal and clay areas.

The maximum difference between final dredging depth and design cut lines in the 10 closed CUs ranged from 13.2 ft deeper in CU-4 to 3.9 ft. deeper in CU-6; conversely the maximum difference between shallower dredging depths and the design cut lines ranged from 3.8 ft shallower in CU-8 to 0.6 ft shallower in CU-7 (locations where bedrock or clay was encountered). Design cut lines were exceeded in all CUs; the average difference between the design cut lines and actual dredging depth ranges from 0.7 ft in CU-6 to 6.3 ft in CU-1.

2.2 Dredged Sediment Volume was 80 Percent Greater than Design Volume

Bathymetric surveys were conducted in 2005 (during design) and just prior to dredging in 2009. The most recent pre-dredging bathymetric survey data (2009), where available, were used to calculate volumes. The volume removed during each dredging pass was calculated for the 10 CUs that were closed during Phase 1. The volume for the first dredging pass was calculated by comparing post-dredging bathymetry to the 2009 pre-dredging bathymetry. Since the 2009 pre-dredging bathymetry was not available for shoreline areas, 2005 pre-dredging bathymetry was used in conjunction with the 2009 data. For the remaining dredging passes, the volume was calculated by comparing post-dredging bathymetry for each pass to the bathymetry for the previous pass. The total volume dredged per CU was calculated by adding the volume dredged during the individual dredging passes. As a check on this sum, the net volume was also calculated by subtracting the elevations of the final dredging pass from the pre-dredging elevations. The total volume calculated from the dredging passes was within 1 percent of the net volume, indicating close agreement within the bathymetric surveys and high survey precision. The volumes dredged for all 10 CUs (rounded to the nearest 100 CY) are listed in Table II-2.1-2. The total dredged volume for the 10 CUs ranged from 48,700 CY in CU-1 to 15,600 CY in CU-17. The total volume dredged during Phase 1 for the 10 CUs is 268,500 CY. The final dredging depth and the pre- and post-dredging elevations for all the 10 CUs are shown in Appendix II-A.

The calculated dredging volume is about 80 percent greater than the design volume estimated by GE. The first dredging pass removed 49% of the total dredged volume, on average, in all CUs. It should be noted that the design volume was estimated using the 2005 bathymetry and did not account for rip-rap and structural offsets, which make the area to be dredged smaller and reduce the expected amount of dredging. To get a better representation of the increase between designed and actual dredged volumes, the design volume was recalculated by EPA using the 2009 bathymetry and adjusted to include the rip-rap and structural offsets. For 9 of the 10 CUs the adjusted design volume was less than or equal to the original design volume estimate. For CU-1, the adjusted design volume was larger than the earlier estimate. The increase in expected volume in CU-1 is attributed to deposition experienced there from 2005 to 2009. The actual dredged volume from all CUs was about 2 times the adjusted design volume. If CU-1, the CU with the greatest increase, is not included in the total volume dredged, the increase in total volume dredged is 1.9 times the adjusted design volume. The volume increase by CU ranged from 3.5 times the adjusted volume in CU-1 to 1.6 times the adjusted volume in CU-18.

2.3 Roughly Half of the SSAP Cores Failed to Penetrate the Full Depth of PCB Contamination

As shown in Figure II-2.3-1 and Table II-2.3-1, the number of complete (Level 1A where the DoC is defined) SSAP cores varies significantly throughout the Phase 1 CUs. The fraction of complete SSAP cores ranges from less than 10 percent in CU-1 to more than 90 percent in CU-17 and CU-18, with an average of about 48 percent. The median value is about 50 percent for Level 1A cores. Together, Level 1A and Level 2A (“nearly complete”) cores comprise 65 percent of SSAP cores on average (median of 62 percent), make up less than 40 percent of the cores at CU-1 and CU-6, and more than 96 percent of the cores at CU-17 and CU-18. When abandoned core locations are excluded the medians are 52 percent for Level 1A cores per CU and 65 percent Level 1A and Level 2A cores per CU. In most CUs roughly half of the SSAP cores did not penetrate the full thickness of PCB-contaminated material. At locations where the cores were incomplete the design DoC and dredging cut lines were necessarily extrapolated (Phase 1 DAD, GE, 2005).

Many of the incomplete cores (both SSAP and post-dredging cores) were a result of refusal during coring. The core refusal was often found later to be due to wood debris in the contaminated sediment mass. Alternate sediment core collection methods that can penetrate wood debris should be considered for Phase 2, as the data gaps associated with the large number of incomplete cores were likely a contributing factor to the underestimated design cut lines.

The percent recovery of the SSAP cores was also compared to the amount of additional dredging required in comparison to the design cut lines and the SSAP core DoCs (refer to Table II-2.3-2). The percent recovery was calculated using the length of the sediment column recovered in each SSAP core divided by the total depth to which the core was advanced. For the subset of SSAP cores with percent recovery less than 60 percent, the amount of additional dredging required was approximately 2 feet or more in comparison to the design cut lines and SSAP core DoC. For the subset of SSAP cores with percent recovery greater than 60 percent, the average amount of additional dredging required decreased to around 1.3 feet in comparison to the design cut lines. Even at SSAP core locations with a higher percent recovery, the required amount of additional dredging was about 1.5 feet, further supporting the incorporation of a design overcut.

2.4 CUs with Larger Numbers of Incomplete SSAP Cores had Larger Differences between Final Dredging Depth and Design Cut Lines

Figures II-2.4-1a, b and c show how the number of complete SSAP cores affected the accuracy of the design cut lines within a particular CU. At locations where there were low percentages of complete cores (higher percentages of incomplete cores), the design cut lines were significantly underestimated and greater volumes of unexpected contaminated sediment and/or wood debris were removed. As shown in Figure II-2.4-1c, as the percentage of complete SSAP cores increases the percentage of core locations where the dredging depth was underestimated by over 2 feet decreases, *i.e.*, the discrepancy between the final dredging depth and design cut line generally decreases. At some locations, such as CU-6 and CU-5, this trend was mitigated by large areas of bedrock that caused dredge bucket refusal before the design cut line was met.

It is concluded that when a larger proportion of complete SSAP cores were collected from a CU, the design cut line was closer to the final dredging depth; conversely, when more SSAP cores were incomplete, the design cut line was less reliable. Again, it must be recognized that even when almost all of the SSAP cores were complete as in CU-18, the DoC was underestimated and dredging extended 0.8 feet below the design cut line on average, strongly indicating the necessity for incorporation of an overcut in the Phase 2 design. In CU-17, much of the area did not require additional dredging (this area was closer to the navigation channel), however, a large strip along the shoreline required multiple dredging passes to remove the inventory, and the average underestimation of DoC for the CU was approximately 0.8 feet.

2.5 Co-located SSAP Cores Show High Variability in DoC

The variability in DoC at SSAP core locations was tested by comparing pairs of high confidence, Level 1A SSAP cores that were collected within 5 feet of each other (co-located). These cores capture the entire thickness of contaminated sediment at their locations, so by comparing co-located Level 1A cores, the variability in DoC can be tested between locations where it is known with high confidence. Twenty nine co-located pairs of Level 1A cores were found within the planned Phase 1 CUs (CUs 1-18, including CU's not dredged during Phase 1). The comparison of DoC found in the 29 pairs yielded:

- 11.2 inch average difference in DoC between paired cores.
- 1 pair with 0 inches difference in DoC.
- 9 pairs with 6 inches difference in DoC.
- 19 pairs with difference in DoC > 6 inches.
- 19 pairs with difference in DoC > 9 inches.
- 12 pairs with difference in DoC = 12 inches.
- 7 pairs with difference in DoC > 12 inches (maximum difference in DoC was 22 inches).

This shows that at high-confidence, complete cores, there is on average about one foot of uncertainty in DoC. The 6-inch incremental staggering of DoC reflects the core segmentation for laboratory analysis.

The analysis was also conducted by removing co-located cores from the East Rogers Island area. The adjusted analysis came to essentially the same results: two thirds of the comparisons had at least 12 inches or greater difference with an average of 10.7 inch difference (0.5 inches different than with East Rogers Island Included). Also the two extremes of 0 inch difference and 22 inches both came from East Rogers Island; without East Rogers Island the range is 6 to18 inches of difference between DoC in co-located cores.

The variograms shown on Figure II-2.5-1 were calculated using SSAP data as part of the Intermediate Design Review and characterize the spatial correlation in DOC at the Rogers Island and East Griffin Island areas. In general, the nugget effect implies random error among proximate locations of at least 9 to 10 inches, that is to say that if two cores are collected near each other, a difference in DoC of 9-10 inches can still be expected. The co-located SSAP core comparisons are equally if not more valid estimators of nugget effect and are considered as independent estimates of the same parameter.

2.6 Significant Bathymetric Changes Occurred Prior to Phase 1 Dredging

Significant bathymetric changes experienced in the Phase 1 CUs prior to the start of dredging represented significant movement of contaminated sediments, contributed to the uncertainty in DoC, and complicated the establishment of accurate design cut lines, as described in further detail below. Overall, the bathymetric survey comparison indicated that the river is dynamic and that changes in sediment elevation are not simply due to debris removal, as asserted by GE.

To evaluate the changes in pre-dredging elevations, the 2005 bathymetry, used to design the dredge prism, was compared with the 2009 pre-dredge bathymetry. Figure II-2.6-1a to j depicts the changes in elevations from 2005 to 2009. Areas that show increase in elevations (*i.e.*, deposition) are color-coded using greens and blues while areas that show decrease in elevations (*i.e.*, erosion) are color-coded using yellow, orange, and red. Areas with 3 inches or less of change are color-coded using grey.

Analyses of bathymetric data from 2005 to 2009 indicated that the river bottom is dynamic with a highly variable distribution of depositional and erosional areas. The comparison shows that CUs east of Rogers Island have experienced deposition and erosion but the CUs West of Rogers Island and East of Griffin Island have experienced just erosion. The majority of CU-1 experienced deposition with pockets of erosion. On an average this CU experienced deposition with an average increase in elevation of 0.3 feet (3.6 inches). The erosion and deposition patterns for the rest of the CUs east of Rogers Island are not evenly distributed. For CU-2 and CU-4 deposition greater than 2 feet was observed in pockets of the navigation channel. The navigation channel in CU-4 also experienced erosion on the order of 2 feet or more. Deposition on the order of 1 foot was observed in isolated areas of the navigation channel in CU-3. CU-5 experienced erosion on the order of six inches with isolated pockets experiencing erosion greater than 2 feet. In the majority of CU-6 the change in elevation for 2005 to 2009 was within a few inches, with smaller areas along the eastern shoreline experiencing erosion up to 1 foot. CU-7 experienced up to 2 feet of erosion along its eastern edge. The change in elevation for the rest of the CU was within 3 inches. CU-8 experienced higher magnitude (greater than 2 feet) of erosion along the edges of the smaller islands. In rest of CU-8 erosion on the order of 3 to 12 inches was observed. CUs east of Griffin Island experienced erosion on the order of 6 inches with some isolated pockets experiencing up to 1 foot of erosion. Table II-2.6-1c lists the change in pre-dredging elevation from 2005 to 2009 for all 10 CUs that were closed during Phase 1 dredging.

The amount of sediment moved by the river in the Phase 1dredge areas from 2005 to 2009 was also quantified by comparing the 2005 and 2009 bathymetry. The volume of sediment eroded and deposited was calculated over the 10 CUs and the area within 30 ft of each CU. Table II-2.6-1d lists the volume eroded and deposited for all ten CUs.

Approximately 11,500 cy of sediment was moved by the river from 2005 to 2009. The net deposition was 9,800 cy over the 68 acres while the net erosion was approximately 21,300 cy. CU-1 and CU-2 were the only CUs which experienced net deposition. The rest of the CUs experienced net erosion with volumes ranging from 300 cy to 3,400 cy.

A similar analysis was performed to compare single beam 2001 bathymetry data to 2005 multi-beam bathymetry data to evaluate the change in elevation experienced in the Phase 1 CUs. During the time period 2001-2005, the river experienced net erosion (all CUs were characterized as net erosional, unlike the 2005 to 2009 comparison) and the changes documented by the surveys are even larger than those calculated for the 2005 to 2009 comparison. The changes in elevation and volume experienced between 2001 and 2005 are summarized in Tables II-2.6-1a and II-2.6-1b. For example, the net erosion between 2001 and 2005 was 24,000 CY for all Phase 1 CUs.

2.7 Significant Bathymetric Changes Observed at SSAP Core Locations

The bathymetric changes described above also had implications for the use of SSAP core data to develop design cut lines. To further evaluate the variability in DoC, the amount of bathymetric change experienced at SSAP core locations between the time of collection to when the dredge prisms were designed to the implementation of Phase 1 was assessed. The SSAP cores were collected over the period from 2002 to 2007, so comparing SSAP data to the bathymetric changes that occurred between surveys gives an idea of the magnitude of the fluctuations that occurred at the SSAP core locations. Since the elevation of the river bottom where SSAP cores were collected was not determined at the time of core collection, the 2005 bathymetry was used to design dredge prisms using DoC from the unreferenced (no elevation measurement) cores. For this reason, the bathymetric variability is incorporated into the DoC and the designed dredge prism. Note that water depth was recorded at the time of core collection, however, water depth can vary by up to a foot during any given day. The results of the comparisons yielded:

<u>For 2001 to 2005</u>:

- Number of measurement points: 773 locations.
- More than 12 inches of erosion: 133 locations (17 percent).
- More than 12 inches of deposition: 60 locations (8 percent).
- More than 6 inches of erosion: 230 locations (30 percent).
- More than 6 inches of deposition: 120 locations (15 percent).
- Between 6 inches of deposition or erosion: 423 locations (55 percent).
- Greatest erosional change: -8.13 feet.
- Greatest depositional change: 7.51 feet.

- Median change: 0.19 feet of erosion.
- Average change: 0.28 feet of erosion.
- Standard deviation: 1.18 feet.

<u>For 2005 to 2009</u>:

- Number of measurement points: 469 locations.
- More than 12 inches of erosion: 11 locations (2 percent).
- More than 12 inches of deposition: 10 locations (2 percent).
- More than 6 inches of erosion: 44 locations (9 percent).
- More than 6 inches of deposition: 38 locations (8 percent).
- Between 6 inches of deposition or erosion: 387 locations (83 percent).
- Greatest erosional change: -3.15 feet.
- Greatest depositional change: 2.88 feet.
- Median change: 0.17 feet of erosion.
- Average change: 0.12 feet of erosion.
- Standard deviation: 0.48 feet.

There was significantly more variability between the 2001 and 2005 surveys than between the 2005 and the 2009 surveys. The 2001 to 2005 comparison considered all CUs planned for Phase 1 and the 2005 to 2009 comparison considered only the CUs actually dredged in Phase 1. Given that 2001 to 2005 is the period when most of the SSAP cores were collected (the 2007 cores were collected to characterize the shorelines), about half the core locations had more than 6 inches of fluctuation prior to the design of the dredge prism. When this is considered with the uncertainty between high confidence co-located cores (Section II-2.5), it is clear that these factors contribute at least one foot of uncertainty to the DoC associated with any given SSAP core location.

2.8 Impact of the Incorporation of a Design Overcut on Removal Volume

On February 17, 2010, GE presented to the peer review panel that over-dredging by 9 inches in Phase 2 would result in unnecessarily dredging between 400,000 and 700,000 CY of clean sediment. First, the Phase 2 area is about 435 acres. This is equivalent to about 2,100,000 square yards. 700,000 CY divided by 2,100,000 square yards is equal to 1/3 yard or 1 foot. So, by GE's calculation, over-dredging will result in ½ to 1 foot of clean material removed everywhere beneath Phase 2 CUs, and DoC must therefore be assumed to be well known everywhere.

A more practical approach to estimating the clean material that might be removed by over-dredging is to look at the CU area in Phase 1 where clean material was found after each dredging pass. Assuming that overdredging will remove clean material at these locations presents a good estimate of the relative proportion of clean material that could be removed during Phase 2. Of the 433 nodes dredged in the first dredging pass, 33 were abandoned and post dredging samples were collected at 409 nodes, of these only 50 (12 percent) had Total PCB concentrations less than 1 mg/kg and only one was non-detect. The Phase 2 area is approximately 2,100,000 square yards. An equivalent 12 percent proportion of the Phase 2 area is 252,000 square yards. Nine inches is equal to 0.25 yards, so the amount of clean material that could be taken out on first dredging passes would be about 63,000 cubic yards. Similar calculations can be made for nodes where PCBs were not detected (these are the only truly clean nodes) and for nodes that were abandoned (these represent areas where no over-dredging can occur) and for all dredging passes. Table II-2.8-1 shows this calculation based on the number of nodes less than 1 mg/kg, nodes that where PCBs were not detected and nodes that were abandoned for all dredging passes of Phase 1. The results of these calculations show if conditions are similar in Phase 2 as to Phase 1, then about 140,000 cubic yards of sediment containing less than 1 mg/kg Total PCB of which only 7,000 cubic yards are actually clean (no PCBs detectable) can be expected to be removed by incorporation of a design overcut. Conversely, abandoned areas equate to about 160,000 cubic yards of material that will not be dredged by an overcut.

3. Evaluation of the Adequacy of Phase 1 Design Cut Lines to Address Full Contaminated Sediment Inventory

Estimation of in-place contaminated sediment inventory was an ongoing process throughout the design period. During the review of GE's Phase 1 Dredge Area Delineation report, EPA and GE examined several different methods to estimate the PCB sediment inventory. The estimates prepared by GE in (GE, 2008) were used to revise the Resuspension Standard and serve as the basis of the analysis discussed below. A detailed presentation of the individual CU mass estimates was prepared by GE (Parsons, 2009) and submitted to EPA at the commencement of the Phase 1 dredging effort.

The initial mass estimates were subsequently adjusted by EPA based on field conditions and offsets and used to estimate the actual PCB mass removed during the initial dredging pass. For subsequent dredging passes, the PCB mass removed was calculated from the post-dredging core data, as described in Section II-3.1. The density used in the latter calculation was derived from the information provided in the (Parsons document) and is also discussed in Section II-3.1.

The actual mass removed, the design mass estimate, and adjusted design mass estimate for Total and Tri+ PCBs are shown on Figure II-3-1. All mass values are presented in Table II-3-1.

Mass calculations show that the Total PCB mass removed followed the same trend as the final sediment volume removed (refer to Section II-2.2), exceeding the design and adjusted design estimates in all CUs. The increase in Total PCB mass removed over the design estimate ranged from 6 percent in CU-5 to a multiple of 4.2 in CU-1, with the greatest differences observed in CU-1 (4.2-fold increase), CU-2 (1.9-fold increase), CU-7 (1.8-fold increase), and CU-8 (2-fold increase). The increase in Total PCB mass removed in comparison to the adjusted design estimates ranged from 38 percent in CU-5 to a multiple of 4 in CU-1. The greatest differences were observed in the same CUs, *i.e.*, CU-1 (4-fold increase), CU-2 (1.9-fold increase), CU-7 (2.9-fold increase), and CU-8 (2.6-fold increase). Program-wide, the Phase 1 Total PCB mass removed exceeded the design mass estimate by a factor of 1.5, and the adjusted design mass estimate by a factor of 1.8.

Differences between the actual Tri+ PCB mass removed in each CU and the design and adjusted design estimates were similar to those observed for the Total PCB mass, with the exception of the location of the minimum differences; for Tri+ PCBs, these were observed in CU-6 rather than CU-5. The increased PCB masses removed compared to those expected by the design support the conclusion drawn from the volume analysis that the DoC was not well characterized during the design phase.

Estimates of the amount of PCB mass (based on both Total and Tri+ measures) and the volume of sediment that would be removed from each CU during Phase 1 activities were initially developed for the Final Phase 1 Design. These estimates are based on bathymetric survey information obtained during 2005. Bathymetric surveys were also performed in 2009, mapping a river-bottom surface expected to more closely resemble the conditions immediately before dredging. The design estimates were adjusted to reflect changes in the river bottom and offsets due to rip-rap and bridge abutments. The revised estimates also excluded CU side slopes.

3.1 PCB Mass Removal Estimate

The PCB mass removed per dredging pass was estimated using the average PCB concentration multiplied by the volume removed and the average bulk density for each CU as follows:

$$M_{PCB} = C_{PCB\ ave} \times V \times \rho_{ave} \qquad \text{Eq. 1}$$

where

M_{PCB} = Mass of PCB

$C_{PCB\ ave}$ = Average PCB concentration for each CU per dredge pass

V = Volume of sediment removed per CU per dredge pass

ρ_{ave} = Average bulk density of each CU

The source for each of the terms used to estimate the mass of PCB is explained below.

3.1.1 Average Bulk Density

The bulk density used for the mass estimate was obtained from different sources provided by GE. The bulk density was calculated from the designed mass of PCB, volume of sediment removed and average Total PCB concentration for each CU. The design volume of sediment removed and average Total PCB concentration for each CU were obtained from a report from GE to EPA entitled "Hudson River PCBs Superfund Site - Resuspension Performance Standard Exceedance of 7-Day Running Average Control Level Criteria - Engineering Evaluation Report" dated July 15, 2009 [GE, 2009]. The Table in page 9 of the report listed the average PCB Tri+ and Total by volume in mg/kg, total inventory sediment removed in cy, inventory removed as of 7/4/09 and current dredging status for each CU. The average Total PCB and the volume were summarized in Table II-3.1.1-1 in this report.

The design mass of PCB was obtained from a map created by Parsons for GE entitled "Phase 1 Certification Unit Locations and Summary Info Hudson River PCBs Superfund Site" (Figure 1, Parsons 2009). The map listed the Total PCB mass in kg, total dredge inventory in cy, area in acres, primary sediment type for each CU. Note that GE reported an alternate set of inventory estimates in their Phase 1 Evaluation Report. Some estimates changed by as much as 40 percent. The reason for these revisions by GE is unknown.

The CU-specific dry bulk density used for the PCB mass calculation consisted of an average for each CU because, as described below, sediment texture was found to be extremely heterogeneous within the CUs and the visual identification of bulk density in subsequent passes was also suspect. The bulk density was actually analyzed for each core segment in the SSAP program. The subsequent post-dredging cores did not have an analysis of bulk density for each core segment, but were based on visual observations.

Based on this information the average bulk density for each CU was calculated and the results can be found in Table II-3.1.1-1.

3.1.2 Average PCB Concentration of the Sediment Removed

The PCB concentration for the sediment removed was calculated using the average of the post-dredging cores per CU except for the initial dredging pass. For initial dredging pass, the design average Total PCB concentration by volume as listed in Table II-3.1.1-1 was used. For the subsequent dredge passes, the average PCB concentration was calculated based on the post-dredging cores. For example, in CU-4 after the first dredge pass, 42 post-dredging cores were collected. The average and median Tri+ PCB concentration of the surface (0 to 6 inch) segment was 28 and 11 mg/kg, respectively. Therefore, the entire CU needed to be re-dredged. As part of the delineation process, the post-dredging core segments below 6 inches were analyzed until the bottom of the contamination was found (*i.e,* Total PCB less than 1 mg/kg in the segment). The core segments above 1 mg/kg are listed in Table II-3.1.2-1. These core segments represent the material being removed in the second dredge pass. The average Total PCB concentration for these cores was 185 mg/kg. After dredge pass 2, there were 14 nodes that needed to be re-dredged (Table II-3.1.2-2). The average Total PCB concentration of the post-dredging cores for those 14 nodes was 142 mg/kg. This concentration represents the average Total PCB concentration of the material removed in dredge pass 3. After dredge pass 3, there were eight nodes that needed to be re-dredged (Table II-3.1.2-3). The average Total PCB concentration of these 8 nodes was 45 mg/kg. Due to schedule restrictions (close of the canal navigation season) these nodes were capped.

The average Total PCB and Tri+ PCB concentrations for materials removed during each dredging pass in the individual CUs were calculated using the data obtained from the post-dredging cores collected at the conclusion of the previous pass. These concentrations were then used in conjunction with the volume dredged during each pass and CU-specific dry bulk density values provided by GE (GE, 2009a) to determine the PCB mass (based on both Total and Tri+ measures) removed during the dredging pass.

3.1.3 Volume of Sediment Removed

The volume of sediment removed per dredging pass was obtained from the bathymetry survey provided by GE. Detail discussion of the methodology and result can be found in Section II-2.2.

3.1.4 Example of Total PCB Mass Calculation

Table II-3.1.4-1 shows an example of the Total PCB mass removed per dredging pass for CU-4. For example, for dredge pass 2, the average Total PCB concentration was 185 mg/kg, average bulk density was 0.8 kg/L and the volume of sediment removed was 14,400 cy. Multiplying all the three numbers, along with conversion factors, resulted in 1,630 kg of Total PCB mass:

$$185 \text{ mg/kg} \times 14{,}400 \text{ cy} \times 0.8 \text{ kg/L} \times 764.55 \text{ L/cy} \times 1 \text{ kg}/10^6 \text{ mg} = 1{,}630 \text{ kg}$$

3.2 Evaluation of GE's Use of SSAP Core Data and Post-Dredging Core Data to Estimate Removal Mass

GE planned to remove 144,439 CY of sediment from dredged Phase 1 CUs. GE and EPA reported removal of similar contaminated sediments volumes: 286,354 CY and 267,804 CY, respectively; however, GE and EPA estimated the mass of PCB removed to be 16,320 kg and 20,020 kg, respectively, an absolute difference of 3,700 kg.

It is important to resolve the discrepancies in the GE and EPA mass estimates. Understanding the root cause of differences between these mass estimates is important to interpret loading data to the Lower Hudson River and compliance with the Residuals and Resuspension Standards. As explained in this section, GE's estimate of the mass removed is unreliable. The potential root causes of the discrepancy are:

1. Low bias of PCB concentration in SSAP samples near and below the design elevation.
2. Differences in handling of bulk density.
3. Order of operations in mass calculations—product of averages vs. sum of products.
4. Weighted vs. un-weighted averaging.

EPA and GE base their mass calculations on different sets of PCB concentration data. GE uses a combination of post-dredging samples and SSAP cores. Regardless of calculation methods, a difference in the distribution of PCB concentrations among the two data sets would necessarily cause problems with reconciliation of any other steps in the process.

Because the post-dredging core samples were collected from the nodes of a regularly-spaced grid, and because the post-dredging core samples fully penetrate the 6-inch layer below the design cut lines, the un-weighted arithmetic average of PCB concentration in post-dredging core samples is an unbiased estimator of the concentration within the 6-inch interval below the design cut lines. Because of the prevalence of up to several feet of unexpected PCB inventory found below the design cut lines, it is clear that DoC as inferred from the SSAP cores was frequently understated. Because the SSAP cores frequently do not fully penetrate the PCB-contaminated layer, one should expect that SSAP samples would be biased low.

Because the post-dredging core data are known to be representative (unbiased) of the concentration in the 6-inch layer of interest, SSAP data should not be included in the mass estimation procedure without first demonstrating that they are equally unbiased.

In the Phase 1 CUs, the median PCB concentration for SSAP cores is less than that for the corresponding post-dredging core distribution. Under the null hypothesis of equal median concentrations, the probability of observing fully 100 percent of the medians from the SSAP population below that of the post-dredging core population is 0.510 = 1/1000. This strongly suggests that the SSAP data are not representative of PCB concentrations in the 6-inch layer of sediment directly below the design cut lines, as shown in Figure II-3.2-1.

The calculation and comparison of geometric means for the post-dredging and complete SSAP cores suggests that the bias of the SSAP cores for estimation of concentration, and by extension mass below the design cut lines, is significantly and substantively biased.   Further evaluations of other root causes would not be productive until GE can re-calculate their estimates without reliance on the SSAP data.

Because complete SSAP cores by definition have observed clean sections below the DoC elevation, they are observable. In contrast, a high proportion of SSAP cores did not fully penetrate the PCB-contaminated layer. Incomplete cores by definition have concentrations greater than 1 mg/kg below their deepest recovered sections, but they are unobservable. Therefore the low concentration fraction of the population is over-represented by the observable complete cores retained in the mass estimation analysis.

Because of this situation, the net effect is that unobserved core sections are likely to have higher concentrations than those that were observed in the bottoms of nearby complete cores. Observable core sections in complete cores preferentially sample the lower concentration fraction of the unexpected PCB inventory. This hypothetical example illustrates the bias in estimated concentration that is likely. This is consistent with results seen in practice comparing SSAP and post-dredging core samples above.

There is no indication that differences in distributions could be due to spatial heterogeneity induced by the lack of collocation of sampling locations. Both SSAP and post-dredging sampling plans are based on regular systematic grids and therefore should both be representative of the concentrations within the CU.

Based on what appear to be understatements of total mass removed, GE has also stated that the percentage of mass removed declines rapidly with successive dredging passes (*i.e.*, with depth). Because of the nature of the bias in the SSAP cores with depth it is fully expected that the difference between SSAP and residuals core PCB concentrations would increase with depth. This suggests that the apparent reduction in percentage mass removed identified by GE may actually be a spurious consequence and that the bias in SSAP and residuals samples increases with depth.

GE argues that dredging beyond the first or perhaps second pass is inefficient based on these mass estimates, which unlike EPA's estimates, decline substantially on a per volume basis with increasing depth. This tendency to understate mass also clouds issues related to evaluation of compliance with the Residual Standard and the benefits of the active remedy and also understates the extent to which the DoC delineations failed to accurately target the depth of contamination. This evaluation is presented in Appendix II-J.

3.3 Case Study of Mass and Volume of Sediment Removed in CU-4

This section examines the mass and volume removed for CU-4 as estimated by EPA & GE due to the large difference in mass estimates. Table II-3.3-1 summarizes the mass and volume estimates by GE and EPA for CU-4. The mass estimates differ by about 40 percent even though the volumes are comparable, with GE estimating about two percent more volume removed than EPA; therefore, the difference is in the methodology. Differences in bulk density and Total PCB concentration for the CU used by GE and EPA are likely contributing to a very different result. For example, in dredge pass 1, GE's mass estimate was approximately 1,000 kg less than that of the EPA. If a bulk density of 0.8 kg/L was used, then the average Total PCB of the sediment being removed was approximately 155 mg/kg in GE's calculation, which is about 40 percent less than the Total PCB concentration used by EPA (235 mg/kg). The Total PCB concentration used by EPA was the average concentration of all the residual core segments that were dredged.

If it is assumed that GE used an average concentration for the CU-4 dredge pass 1 of 235 mg/kg as calculated by EPA, then the bulk density used by GE to obtain a Total PCB mass of 1,700 kg would have to have been about 0.49 kg/L, which would only be accurate for a primarily organic material. GE Table H-1 lists the mean bulk density by sediment type and the mean bulk density for organics was 0.47 kg/L. The use of 0.49 kg/L bulk density is not supported by the primary sediment type reported in the Parsons Figure 1 map. This figure lists the primary sediment type for CU-4 as 11% clay and silt, 39% fine sand and 24% coarse sand.

In Table 4.2-3 of GE Draft Phase 1 Evaluation Report, the footnote for CU-4 indicated that the dredging was halted prior to meeting the design cut line. Assuming that the volume removed to meet grade during the design dredge cut was 18,300 cy, as listed in July 15, 2009 Resuspension Engineering Evaluation Report (GE, 2009), the volume of undredged sediment was about 375 cy. Using a bulk density of 0.8 kg/L and the design Total PCB mass of 2,835 kg, the average concentration of the undredged material would be approximately 5,000 mg/kg (Table II-3.3-2). Note that GE reported an alternate estimate of inventory volume and mass in the Draft Phase 1 Evaluation Report. Table II-3.3-3 summarizes the different estimate of inventory volume and mass from different sources. The reason for the volume reduction in the Draft Phase 1 Evaluation Report was assumed to be the adjustment due to setbacks in areas of rip-rap, bridge piers, walls, etc.; however, GE did not mention whether the adjustment took into account the bathymetric changes from the 2005 to 2009 survey. The net change in volume based on bathymetry change from 2005 to 2009 in CU-4 was about -1,000 cy. The EPA estimate for the change in volume due to setbacks was approximately -200 cy. Another volume reported by GE can be found in memo regarding Adjustment and Pro-rating of Phase 1 Mass-Based PCB Load Criteria (GE, 20008). This memo lists the volume dredged by CU and for CU-4 the volume was 19,600 cy. Although it was only a small amount of change from 19,600 to 18,300 cy (approximately 7%), the reason for this change is unknown.

While the inventory volume reduction can be explained, the reason for the inventory mass revisions by GE is unknown. Notably, the mass of Total PCB reported in the Draft Phase 1 Evaluation Report was approximately 20% less than the estimate in the Parsons Figure 1 map (Parsons, 2009).

If the smaller design mass estimate was used (2,350 kg), the average concentration of the un-dredged material would be approximately 2,800 mg/kg (Table II-3.3-2). This high average concentration led to a conclusion that GE methodology in calculating the mass by incorporating the SSAP cores suggests that the high concentration SSAP core segment was not dredged. A closer examination of the SSAP core and the surface elevation after dredge pass 1 reveals that nodes with high concentration segments were removed in the first pass. Therefore, the high concentration Total PCB concentration in the un-dredged material was not supported by the data. A discussion on the applicability of SSAP cores to mass estimation can be found in Section II-3.2.

4. Evaluation of Post-Dredging Core Collection and Management of CU Re-dredging Passes

This section evaluates the implementation of the Residuals Standard during Phase 1 with regard to post-dredging core collection, associated data interpretation, and the management of additional dredging passes required prior to CU closure. To summarize, the underestimate of DoC described in Section II-2.0 created a 'ripple effect' that led to multiple dredging passes in each CU to identify and capture the contaminated sediment inventory missed by the initial design cut lines. The process of re-dredging was time-consuming and data that could have been obtained from the post-dredging cores were not proactively used to re-characterize DoC at CUs with missed inventory.

The multiple dredging passes required to remove missed inventory confounded the ability to truly examine the performance of the Residuals Standard, since the standard was intended to manage comparatively thin layers of dredging residuals following removal of all contaminated sediment inventory (ideally through dredging to the initial design cut lines). Concerns were raised during development of the Residuals Standard that the focus on re-dredging would result in excess dredging in pursuit of a difficult-to-capture residuals "fluff" layer, delaying implementation of the remedy. During Phase 1 only about 7 percent of the total volume removed was considered residuals. The Residuals Standard did not impede the progress of the Phase 1 program, but rather the required sampling was the key to the identification and removal of the previously uncharacterized inventory.

The final dredging volumes confirm that DoC was not well characterized by the SSAP cores; post-dredging cores also did not always accurately identify the DoC. This conclusion is supported by the volume of material removed with each dredging pass as well as the concentrations removed. There should have been a consistent decline in sediment volume and PCB mass removed by the dredging passes that followed the initial dredging pass, but this was not observed in 70 percent of CUs. If the DoC had been correctly characterized, such a decline would have been observed, with additional passes necessary to remove only residual sediments. Instead, as shown in Table II-2.1-2, the first pass achieved less than 50 percent removal of the sediment volume in 6 of the 10 CUs. Overall, only 49 percent of the Phase 1 volume was removed on the first pass. Even the second pass only achieved an additional 30 percent of the total volume. The substantial volumes removed by the second, third, fourth, and even fifth dredging passes show that the majority of re-dredging was conducted to remove inventory sediments.

At most of the CUs, for example CU-1, the retrieval of incomplete post-dredging cores appears to be due to debris in the sediments causing refusal of the coring apparatus; at other places the inventory depth was simply thicker than expected when coring, the deeper segments were not analyzed, or the core was not advanced sufficiently. Deposits of woody debris in some CUs contributed to post-dredging core refusal prior to full penetration of the contaminated sediment thickness, similar to difficulties encountered during SSAP coring, and also complicated extrapolation of DoC in incomplete cores. In the vicinity of Rogers Island, a significant portion of the contaminated sediments were moved to their current positions as a result of the removal of the Fort Edward Dam in 1973. This material, containing a substantial fraction of woody debris, was difficult to penetrate using the vibracoring technique during the SSAP and overlies the sediment that was deposited by typical riverine processes prior to the dam removal. The distribution of PCB with depth in the sediments beneath the material deposited after the dam removal would be independent of the distribution of PCB within the overlying material. As a result, it is unlikely that there would be a good correlation between the PCB concentrations in the material deposited prior to 1973 and the material deposited after the dam removal. Extrapolations to the DoC in the underlying material deposited prior to 1973, based upon PCB distribution in incomplete cores taken within the overlying material deposited after dam removal, would likely be incorrect.

Every CU completed during Phase 1 was dredged at least 3 times (the initial effort to meet the design cut lines plus at least two additional passes), although the number of core locations requiring inventory removal decreased with every dredging pass. Various levels of inventory remained un-dredged at each CU except CU-17. In some CUs inventory was left in place and capped due to the canal closing schedule. In other CU's some inventory may have been left in place and capped, but the extent of the contaminated sediments left in place is unclear as deeper post-dredging core segments were not collected and/or analyzed.

In CUs 1 to 8 and 18 neither the SSAP cores nor the post-dredging cores penetrated the full depth of inventory at enough locations to accurately characterize the DoC until after the 3rd or 4th dredging pass was completed. For Phase 2, better estimation of DoC and better assurance that initial dredging will remove the targeted inventory are needed. To reduce the amount of additional dredging required after the initial dredging pass, the complete sediment column, to the depth of uncontaminated sediment, should be analyzed immediately after collection for every post-dredging core; and at a minimum, every core must have two contiguous segments below 1.0 mg/kg to establish the DoC. This conclusion is supported by the measured PCB concentrations in the post-dredging cores collected after each dredging pass.

Methods other than those used to collect the SSAP cores (*i.e.*, other than vibracoring) should be considered to assure full penetration of the contaminated sediment, even when there are obstructions such as wood debris, to augment the characterization of areas with many incomplete cores. These methods may include using hammer driven split spoons or hydraulically pressed Shelby tubes, which will be refused by rock and boulders, but will penetrate wood debris. If additional sampling is warranted, the results can be used to refine the uncertainty and the cores can be collected on a year-by-year basis.

While obtaining additional complete cores for the Phase II areas will lead to a more accurate prediction of the DoC, dredging must be conducted in a manner that will compensate for the uncertainty, such as requiring design overcuts and fully removing deposits of wood debris encountered during dredging. Also, time was unnecessarily spent attempting to surgically dredge (fine grading) to a specific DoC that was later proved to be underestimated. Upon reaching the design cut line, the dredging contractor expended effort to 'clean up' the dredged surface to the contract tolerance of 3 inches prior to collecting post-dredging cores. Once the missed inventory was detected, deeper dredging was required, erasing the effort spent to achieve the cut line within elevation tolerances.

The following analyses are included in this section to support the conclusions that additional dredging passes during Phase 1 were required primarily to address missed inventory and that post-dredging core data were not proactively used to manage the re-dredging process:

- Redredging conducted during Phase 1 was primarily to address missed inventory (II-4.1).
- PCB concentrations were examined after each dredging pass (II-4.2).
- CUs with larger numbers of complete SSAP cores required less re-dredging to address missed inventory (II-4.3).
- CUs with larger numbers of complete SSAP cores required fewer re-dredging passes (ii-4.4).
- CUs with larger numbers of complete post-dredging cores required less additional dredging in comparison to design cut lines (II-4.5)
- Post-dredging core data was not proactively and adaptively used to manage the response to the presence of missed inventory (II-4.6).
- More robust efforts should be made to obtain post-dredging samples; some locations were abandoned during Phase 1 (II-4.7).
- The process for collection of post-dredging cores did not prove onerous for the project schedule (II-4.8).
- Collection and processing of post-dredging cores met the requirements of the Residuals Standard and GE's RAM QAPP (II-4.9).
- The post-dredging core locations met the requirements of the Residuals Standard (II-4.10).

- EPA's evaluation of some elements of GE's post-dredging core sampling analytical methods are still ongoing (II-4.11).

4.1 Redredging during Phase 1 Was Primarily Due to Missed Inventory

All CUs were dredged at least 3 times – the initial dredging effort to meet the design cut lines plus at least 2 additional dredging passes. The initial dredging pass removed only 49 percent of the volume and only 58 percent of the mass. During Phase 1, 6 CUs were dredged 3 times, 3 CUs were dredged 4 times, and one CU was dredged 5 times. The number of dredging passes implemented for each CU is presented in Table II-4.1-1a. Table II-4.1-1b shows the total re-dredged areas for both inventory and other non-compliant residuals nodes removal per dredge pass. In general, the amount of area dredged decreased with subsequent dredging passes. During the second dredging pass, approximately 33 acres out of the 43[1] acres that were designated for removal were dredged (approximately 75 percent). Out of the 33 acres, 15 acres (approximately 35 percent) were dredged for inventory removal and 16 acres (approximately 35 percent) were dredged for residuals removal. During the third dredging pass, the non-compliant areas were reduced to 15 acres (approximately 40 percent of the original designed removal area), of which 7 acres were dredged for inventory removal and 8 acres were dredged for residual removal. In the subsequent dredging passes (*i.e.,* fourth and fifth dredging passes), the amount of non-compliant areas dredged became very small, or approximately 3 acres (about 7 percent) of the original designated removal area. Overall, the extent of inventory removal was approximately 70 percent of the area dredged while the residual area was about 30 percent (Table II-4.1-1b). On a volume basis only about 8% of the volume removed could actually be considered residuals.

The distribution of post-dredging core results for each CU after each dredging pass is presented in Table II-4.1-2. The post-dredging data revealed the presence of previously uncharacterized contaminant inventory at depth.

The average number of nodes requiring re-dredging out of all nodes sampled after a particular dredging pass (except at CU-1) shows a consistent decline through the first 3 of 4 dredging passes. For CU-1, the results of cores collected after the second dredging pass showed that the PCB concentrations had not decreased, most notably because the presence of deposits of contaminated wood debris in this CU. Therefore, in this analysis, CU-1 was excluded from the calculation of the average number of nodes requiring re-dredging. Figure II-4.1-1 shows the percentage of nodes that required re-dredging for different CUs and different dredging passes.

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[1] The 43 acres represents the adjusted design area removal based on setbacks.

The red dashed line on the figure indicates the average percentage for all the CUs except CU-1. On average, the percentage of nodes that required re-dredging out of all the nodes sampled are approximately 70, 30, 15, and 20 percent following the initial, second, third and fourth dredging passes, respectively. A fifth pass was conducted only in CU-1; the percentage of nodes requiring re-dredging increased to 95 percent after the fifth pass from the 60 percent that required re-dredging after the initial pass (Table II-4.1-2).

At CU-17 low average sediment concentrations were achieved after the initial dredging pass and most of the missed inventory was removed from a narrow strip along the shoreline. Sediment removal in CU-17 was completed after three dredging passes. After the initial dredging pass, only 10 nodes out of 40 were non-compliant nodes. Seven of these represented inventory nodes. At CU-17, 38 of the 41 cores collected during the SSAP had complete sediment contamination profiles. The actual volume removed from CU-17 exceeded the design volume by one-third and the adjusted design volume by two thirds. The percentage of cores requiring re-dredging out of all cores collected after each pass is shown on Figure II-4.1-1 and Table II-4.1-2.

CU-1 required five dredging passes, which removed more than 3.5 times the designed dredging volume for the CU and left contaminated sediment inventory in place over most of the CU. Ninety-five percent of the sampling nodes showed inventory remaining after the fifth pass (Table II-4.1-2, page 5). CU-1 and CU-17 are not typical of what was seen in the rest of the project area for Phase 1. The east side of Rogers Island (CUs 1, 2, 3 and 4) may also be less typical of what might be expected during Phase 2.

The observation that the number of inventory nodes declined after subsequent dredging passes can be seen in Figure II-4.1-2. This figure shows the percentage of inventory nodes requiring re-dredging for different CUs per dredging pass. It can be seen from the figure that for the second dredging pass (red bar in Figure II-4.1-2) in six out of 10 CUs the percent of inventory nodes requiring re-dredging is less than 20 percent. After the second dredge pass, the inventory nodes requiring re-dredging was less than 10 percent (green and orange bars in Figure II-4.1-2). The average percentage of inventory locations actually detected (out of the total locations sampled) after each dredging pass did not decline in the same way that nodes requiring re-dredging did. Excluding CU-1, the average percentage of inventory nodes out of the number of re-dredged nodes after each dredge pass was approximately 50, 35, 30, and 30 percent for the first through fourth passes, respectively. The percentage of inventory nodes remaining in CU-1 after the fifth dredging pass was 70 percent. The percentage of re-dredging locations considered inventory nodes are shown on Figure II-4.1-3.

If the non-compliant nodes classified as post-dredging > 6 mg/kg are added to the inventory nodes tally, their combined average percentages out of the total nodes requiring dredging increased by 50 to 200 percent with each dredging pass. The observed pattern was a consistent increase after the first, second, and third dredge passes with a slight reduction after the fourth pass. The increase in the percentage of inventory/non-compliant nodes does not represent an increase in the area requiring dredging, but in the number of nodes that represent missed inventory. The respective average percentages (for inventory and post-dredging > 6 mg/kg, combined, excluding CU-1) for the first through fourth passes are approximately 70, 90, 95, and 90 percent, respectively and are shown on Figure II-4.1-4.

To assess approximately how much acreage in each CU required re-dredging due to previously uncharacterized inventory, areas of influence were calculated for each node after each dredging pass. This calculation uses the area of influence of each node as a basis for integration and the results provide an approximation of the areas in each CU requiring re-dredging due to previously uncharacterized inventory. Calculated acreages are presented in Table II-4.1-3.

As expected, the sediment acreages corresponding to previously uncharacterized inventory display trends similar to those observed in the nodes themselves. While the average acreages requiring re-dredging generally decreased in comparison to the total CU area with each pass (Figure II-4.1-5), the CU area requiring re-dredging was composed primarily of inventory sediments (Figures II-4.1-6 and II-4.1-7). Figures II-4.1-6 shows the percentage of inventory area removal out of total area requiring re-dredging.

4.2 Inconsistent Decline or Increase in PCB Concentration with Successive Dredging Passes

The average Total PCB concentration of sediments removed with each dredge pass consistently declined in two of the ten CUs dredged during Phase 1: CU-4, located in the East Rogers Island area and CU-17, located in the Griffin Island Area. For all other CUs, the average Total PCB concentration removed with each pass showed trends of inconsistent decline (CUs 2, 3, 5, 8, and 18) or increase (CUs 1, 6, and 7). The average Total PCB concentrations of sediments removed during each pass are shown on Figure II-4.1.1-1a through c.

The average Tri+ PCB concentration of sediments removed with each dredge pass consistently declined only in CU-4. For all other CUs, the average Tri+ PCB concentration removed with each pass showed trends of inconsistent decline (CUs 2, 3, 5, 17, and 18) or increase (CUs 1, 6, 7, and 8). The average Tri+ PCB concentrations of the sediments removed during each pass are shown on Figures II-4.1.1-1d through f.

4.3 CUs with More Complete SSAP Cores Required Less Re-dredging to Address Inventory

All CUs significantly exceeded the original design dredging volume; the least additional volume was dredged in CU-17 with about a one-third increase. This section discusses the CUs that required lesser amounts of re-dredging.

Those CUs that had a high percentage of "complete" SSAP cores had the least increase in dredging volume and therefore less area requiring re-dredging on subsequent passes. Obtaining a better evaluation of DoC in Phase 2 will reduce the need for re-dredging and capping of inventory.

The percentages of inventory nodes that required re-dredging were examined on a CU-by-CU basis and compared to the number of complete cores obtained during the SSAP. The largest proportions of complete cores (*i.e.,* cores characterized as 1A and 2A) obtained during the SSAP program were collected from CUs 17 (93 percent complete) and 18 (96 percent). At each of these CUs:

- After the first dredging pass, the proportion of inventory nodes was less than 35 percent.
- After the second and third dredging passes, the proportion of inventory nodes was 6 percent or less (in fact, in CU-17 all sampled nodes were compliant after the third dredging pass).

At CUs characterized by higher percentages of inventory nodes (*e.g.,* CUs 1, 2, 7, and 8), fewer complete cores were obtained during the SSAP program (7, 47, 41, and 59 percent, respectively). With fewer reliable data points to characterize the DoC, there was greater uncertainty in the design of the dredging cut lines, resulting in a greater frequency in application of Residuals Standard contingency actions. Figure II-4.2-1 shows the percentage of inventory nodes plus the non-compliant post-dredging > 6 mg/kg Tri+ PCB nodes out of all the non-compliant nodes for different CUs and dredging passes.

The finding described above is further supported by the total acreage in each CU requiring inventory removal after the first dredging pass. The sizes of these areas were also examined on a CU-by-CU basis and compared to the number of complete cores obtained during the SSAP.

Figure II-4.2-2 presents the total acreage in each CU represented by the inventory nodes. The number of complete cores obtained from each CU is presented in Table II-4.2-1II-3.3-4.

4.4 SSAP Core Completion vs. Number and Volume of Successive Dredging Passes

To evaluate how the confidence level of SSAP cores affected dredging implementation in Phase 1, the fraction of the total sediment volume removed during each dredge pass in each CU was plotted in Figure II-4.3-1. As can be seen in the figure, CUs 18, 17, 4 and 3, which had the greatest percentage of complete SSAP cores, were completed with a more efficient sequence of dredging passes, where each successive pass removed less material than the prior pass and dredging was essentially completed in 3 passes (although CU-4 had areas of inventory that were left behind due to the end of the navigation season). CUs 2, 8 and 7 had a lower percentage of complete SSAP cores and required four dredging passes to be essentially completed (again with some areas of inventory left behind). CUs 1, 5 and 6 had the lowest percentage of complete cores and required more dredging after the initial pass. Both CU-5 and CU-6 had significant areas of bedrock and bucket refusal above the DoC and although isolated, the true amount of inventory left behind in bedrock and boulder field areas may not be well quantified at these CUs, but is expected to be minimal. From this evaluation it is apparent that CUs that had more complete SSAP cores were dredged more efficiently and with comparatively better productivity.

The above correlations of SSAP core completion with estimated removal thickness are also shown in Figures II-4.3-2a and II-4.3-2b. It can be seen that the design DoC was better estimated in CU-17 and CU-18 than in CU-1 through CU-8. This is largely attributed to the higher proportions of Level 1A SSAP cores in CU-17 and CU-18 than those in CU-1 through CU-8. Since there were fewer level 1A and 2A SSAP cores in CU-1 through CU-8, the relative increases in volumes of sediment removed over the adjusted original estimates (designed dredging volumes based on 2009 bathymetry and considering rip-rap and abutment off-sets) were quite high. For example, only 2 out of 33 SSAP cores (including abandoned cores) were complete (Level 1A cores) in CU-1, and the increase in dredging volume was nearly 3½ times the adjusted design volume. Similarly at CU-5, just 4 of 24 SSAP cores collected were complete and the actual dredging volume was more than double the adjusted original estimate. Conversely, in CU-18 50 of 52 cores collected were complete, and the volume increase was under 60 percent. This is still a large underestimation of dredging volumes, but it is not as significant as in most of the other CUs.

Table II-4.3-1 provides comparisons between final dredging depths, Phase 1 design cut lines and SSAP core DoC [the bottom of contamination detected in the SSAP core or extrapolated at the core location from an incomplete core by GE (Phase 1 DAD, GE, 2005)]. Removal depth is calculated based on mean elevation in a 3-foot radius around the SSAP core location. The post-dredging elevations were within 3 inches of the design elevations for only 18 percent of the cores, indicating that for majority of the SSAP cores re-dredging was required. For approximately 7 percent of the SSAP cores undercutting was observed either due to the presence of bedrock or structural offsets. 68 percent of the SSAP core locations required more than 6 inches of additional dredging beyond the design elevations, and 54 percent required additional dredging beyond 1 foot. When compared with the SSAP core DoC, 56 percent of the SSAP core locations required an additional 6 inches of dredging and 46 percent required an additional 12 inches of dredging. Tables II-4.3-2a, 2b and 2c show comparisons of final dredging depths, Phase 1 design cut lines and SSAP core DoC for East Rogers Island, West Rogers Island, and East Griffin Island, respectively. The discrepancy between final dredging depth and Phase 1 design cut line (or SSAP core DoC) is the highest for the CUs at East Rogers Island (CU-1 through CU-4) and the lowest for the CUs at East Griffin Island (CU-17 through CU-18). The discrepancy between final dredging depth and Phase 1 design cut line is always higher than the discrepancy between the final dredging depth and SSAP core DoC. As a result, unexpected inventory was found requiring additional dredging and PCB inventory was left in place around Rogers Island, and to a lesser degree, near East Griffin Island.

4.5 Post-Dredging Core Completeness vs. Difference between Initial Cut Lines and Final Dredging Depths

The data from the post-dredging cores are compared to the final dredging depth in Figures II-4.1-1a through j. Table II-4.4-1 presents related information in a tabular form. From Table II.4.4-1, it can be seen that cores were analyzed for inventory (*i.e.,* "Cores where samples below 6 inches were analyzed") on nearly every dredging pass in nearly all CUs. One important observation that can be made when looking at the post-dredging core figures is that at many locations where multiple cores were collected (one after each dredging pass for multiple passes) the concentrations seen in adjacent sediment cores (sediment collected at a nearby location from the same elevation but during different dredge passes) are not the same. Also at many locations samples collected in subsequent cores from lower elevations are higher in concentration than concentration at the equivalent elevation in the adjacent cores collected previously. These differences, which can be seen in all CUs, highlight the heterogeneity of the contaminated sediment and show the need to have two consecutive samples less than 1.0 mg/kg Total PCB from a particular post-dredging core to positively identify core completeness or DoC. Two examples will be discussed in detail below.

In CU-2, which is illustrative of poor post-dredging core data collection and evaluation, 22 first pass post-dredging cores were incomplete (roughly 48 percent of the cores collected; Figure II-4.1-1b). In all cases, the final dredging depth was below the bottoms of these cores. In many core locations, the DoC was established after the second round of post-dredging coring; however, post-dredging cores collected on the third pass show contaminant concentrations similar to the second pass. The fourth pass also yielded concentrations similar to those observed on the prior rounds at the same locations. Consistent with the Residuals Standard, the cores on the last round were not sampled below 6 inches. The consistent levels of contamination in all three rounds indicate the variable nature of the DoC in this area and the continued presence of inventory rather than residuals. Given this similarity in surface sediment concentration, the lack of sampling at depth in this CU creates an uncertainty in assessing whether the DoC was attained in this CU. This concern is part of the basis for the proposed revision to the Residuals Standard that the DoC be determined for all post-dredging cores and is a pervasive issue for nearly all of the CUs.

In contrast, at CU-18, the majority of the post-dredging cores were complete and only three core locations were capped following the requirements of the Residuals Standard. As shown in Figure II-4.4-2j, only residual sediments were capped at these nodes since the DoC was established in a previous post-dredging core.

4.6 Post-dredging Core Data Not Proactively Used to Redefine DoC

For many post-dredging cores, only the top 6-inch segments were analyzed. While this was permitted under the Residual Standard, based on EPA's evaluation of the post-dredging core data and the inherent variability in sediment PCB concentrations, the analytical results from the top 6 inches could not be used to determine whether PCB inventory remained below 6 inches or to confirm the DoC. As shown in Figure II-4.1-1a through j, many post-dredging cores in most CUs penetrated into PCB inventory, but not through the full depth of inventory. This introduces additional and undesirable uncertainty in the delineation of the next dredging pass. Therefore, future post-dredging cores need to fully penetrate the thickness of contamination, preferably documented by 2 contiguous segments in the core profile at less than 1 mg/kg.

For the most part the post-dredging coring was not implemented adaptively so when it was found that the design DoC was incorrect, the coring objectives were not changed to redefine the DoC through most of Phase 1 (near the end of the project, the intent of some cores was changed to include redefining DoC). At several locations, cores were collected and the top 6-inch segments were determined to contain more than 1 mg/kg Tri+ PCB, but the deeper portions of the cores were not analyzed. Despite the improved DoC delineation in these instances, inventory was still left in several CUs, largely due to the closure of the navigation season.

Figures II-4.5-1 and II-4.5-2 which show the amount of additional dredging (deeper than the design cut lines) that occurred at SSAP core locations. Post-dredging cores were often actually measuring missed inventory in the CUs and did not define the actual DoC at many locations. Therefore, it is recommended that the SSAP core information for the Phase 2 design be reviewed, especially where many incomplete SSAP cores occur in close proximity, and that the estimates of DoC be revised to reflect this understanding. Where appropriate, further samples should be collected in these areas (this can be accomplished throughout Phase 2).

4.7 More Robust Efforts Necessary to Obtain Post-dredging Samples from Abandoned Locations

Successful completion of a CU is contingent on successful post-dredging core collection. In a number of instances in various CUs and dredging passes, coring was not possible and either grab samples were obtained after several coring attempts or the site was abandoned when no sample could be obtained, consistent with the approved RAM QAPP (GE, 2009b). Although the Residuals Standard sampling methods were consistently followed in the field, some locations were abandoned after an initial dredging pass but were reoccupied and successfully sampled on subsequent passes. The discussion that follows examines the relationship between sampling success and probe depth and indicates that a wider sampling radius should be used to improve the likelihood that a sample will be collected and fewer sites will be abandoned.

Prior to collecting a post-dredging core, the depth of sediment was measured using a probe. As might be expected, the probing depth reached was greater than the depth of sediment obtained by the subsequent coring attempt. The average probing depth associated with a successful core collection was also greater than the average probe depth associated with a grab sample. A similar relationship between probe depths for successful grab sampling sites and abandoned sites was not observed. Probe depths are summarized on Figure II-4.6-1 and Table II-4.6-1. The distribution of probe depths for all sampling sites ranges widely. These distributions reflect, in part, the natural variability of the thickness of sediment on the river bottom; however, the probing data show an inordinately high frequency of exactly 48-inch probe penetrations. The reason for this is unclear.

Despite the variability, a statistically significant difference is apparent between the successful coring sites and the other two site classes. Figure II-4.6-1 shows a statistical means comparison [performed using the Tukey-Kramer honestly significant difference (HSD) test] among the different sampling success types. The results show a deeper average probe depth for successfully cored sites relative to the other classes; however, the mean probing depths at grab and abandoned sampling locations were not statistically different from each other. When the relationship is examined on a CU-basis, the same relationship between the three site classes is generally observed, although differences may not be statistically significant different due to fewer samples and the wide variation in probe depth (see Figures II-4.6-2 to II-4.6-9). These results indicate that in general, the same sediment thickness probed at abandoned sites is similar to at grab sites.

A total of 73 core locations were initially abandoned (representing an area roughly equivalent to two CUs). Of these, sampling was re-attempted at 27 locations on subsequent dredging passes. Of the 27 locations attempted, 17 coring sites successfully yielded samples. The successfully re-sampled locations were in CUs 1, 3, 6, 8, and 18. Nine of the 17 locations yielded samples that were 16 inches or greater in length and the average Total PCB concentration for the samples collected at these locations is 59 mg/kg and ranges from not detected to 351 mg/kg. EPA notes the sampling crews followed the approved RAM QAPP sampling methods and made three attempts to collect samples from each site prior to abandonment and made several attempts to core prior to grab sample collection. It is likely that in reoccupying a coring site, the sampling crew moved sufficiently far from the original location (but still within the allowed l0-ft radius around that location) to find sufficient sediment to sample. This underscores the degree of local variability of the depth of contaminated sediment, and suggests that the allowed 10-foot coring radius is not sufficient to permit a site to be abandoned.

Before collecting a grab sample or abandoning a location the location should be moved within a 20-ft radius around the assigned sampling location multiple times, or according to field judgment to account for significant variability in bottom conditions as experienced in CUs 5 and 6. The time and flexibility gained by allowing sampling to be performed within a portion of a CU should be used to more rigorously sample each location and avoid abandoned site and grab samples to a much greater extent than in Phase 1.

4.8 Post-dredging Coring and Project Schedule Impacts

During the development and review of the Residuals Standard, some concerns were raised that the requirements for post-dredging sampling were onerous and would significantly impact the dredging schedule. In particular, post-dredging core collection was seen as a time-consuming step that could delay the overall effort. In recognition of this, the standard required that core collection be completed within 7 days of completion of a CU dredging pass; however, with further consideration during Phase 1, EPA and GE agreed to a post-dredging core collection protocol that permitted core collection when major subunits (approximately one acre) of a CU were completed. In this fashion, GE was able to begin collecting cores from the completed upstream end of a CU while the downstream end was still being dredged. In allowing this adjustment, EPA hoped to further reduce the impacts of core collection on the Phase 1 schedule. The analysis presented below examines this issue.

An examination of CU completion dates and post-dredging core collection dates was performed for the individual dredging passes to determine whether the core collection events had any notable impact on the dredging schedule. For the purpose of this analysis, the completion of a dredging pass in a CU was defined as the date of the final bathymetric verification survey, which represents the date when sediment removal to the defined cut lines is confirmed.

Core collection date information is available from two sources: the weekly residuals sediment data exports, and Tables 2.6-5 through 2.6-14 of the GE Phase 1 Data Compilation Report (GE, 2009c). There are minor differences in the two data sets regarding the various dates. In light of the minor differences, the weekly residual sediment data exports were selected since they represent data recorded closer in time to the field activities. In any case, the observations described below are expected to be unaffected by the choice of the data source.

Table II-4.7-1 presents a summary of the individual dredging passes for each CU, along with the dates associated with the completion of dredging, the completion of the bathymetric surveys and the periods of core collection. In total, there were 34 dredging passes completed in the 10 CUs that comprised Phase 1. The periods from completion of the bathymetric surveys to completion of core collection varied from 1 to 37 days, with a mean value of 5.7 days and a median value of 3 days. Most core collection events were less than 7 days in length and in fact involved only three to four field days (see the column labeled "Dates of Associated Post-Dredging Core Collection"). The notable exceptions to the average sampling period were associated with conditions unrelated to core collection, such as the first passes in CU-8 and CU-1, where dredging efforts were affected by local, unexpected conditions, such as the discovery of a contaminated sand bar, a potential cultural resource area in CU-8 and the presence of wood debris in CU-1.

The post-dredging core collection dates were evaluated in two ways to assess how core collection may have impacted the Phase 1 schedule. For the first comparison, the start of core collection was compared to the completion of the dredging pass. In the second, the end of core collection was compared to the completion of the dredging pass. Thus, the first comparison identifies how often GE was able to take advantage of the adjustment to the standard and begin sampling prior to the completion of the CU dredging pass. The second measures how many days were added by core collection to the end of the dredging pass.

The results for both comparisons are summarized in Table II-4.7-1 under the headings "Post-Dredging Core Collection Initiated prior to Dredge Pass Completion" and "Post-Dredging Core Collection within One Day of Dredge Pass Completion", respectively. The details on the extent of coring relative to the dredge pass completion date are given under the heading "No. of Days between Post-Dredging Core Collection and Completion of Associated Dredge Pass".

As noted in the table, on 21 of 34 passes (about 61 percent of the passes), GE was able to begin sample collection prior to the completion of the CU by sampling subunits. Similarly, the core collection efforts were completed within one day or less of the completion of the dredging pass on 21 of the 34 events. Notably, most but not all of the 21 passes where coring was initiated prior to completion of the CU were also where core collection was completed within 1 day of dredging completion. Additionally, 75 percent of the core collection efforts were completed within 3 days of the end of dredging. This information is summarized in Table II-4.7-1.

As is evident in Table II-4.7-1, the actual core collection efforts were short in duration and only infrequently added more than 3 days to the dredging schedule for a CU. Based on these observations as well as the other benefits provided by the core collection efforts, it is concluded that post-dredging core collection provides an important means to monitor dredging success while having only a minimal impact on the remedial schedule; however, if there is not a well defined DoC, multiple dredging passes will result in multiple coring passes and multiple rounds of analysis.

4.9 Sampling Frequency, Depths and Methods

Post-dredging cores were collected following completion of each dredging pass and subdivided into 6-inch sections for chemical analysis. For each core, the 0 to 6-inch interval was immediately analyzed for PCBs. The Total and Tri+ PCB concentrations detected in the samples were evaluated against the Residuals Standard, the PSCP, and CDE action levels described in Section II-1.0. Depending on the results, deeper layers of the cores were analyzed as required by the standard.

As described in the Remedial Action Monitoring Quality Assurance Project Plan (RAM QAPP; GE, 2009b) and the General Electric Contract 4 Drawings (GE, 2007), the ten CUs dredged during the 2009 Phase 1 activities had the following size distribution:

- CU-1 – 3.39 acres.
- CU-18 – 6.10 acres.
- CUs 2 through 8 and 17 – approximately 5 acres.

All CUs except the smallest one were sampled on an 80-foot square grid, yielding 40 node locations per CU. The smallest CU was sampled at a density of 40 nodes on a proportional grid. In addition, any shoreline area within a CU in which the dredging cut lines are shallower than the DoC was sampled at 80-foot intervals along a transect oriented parallel to shore. The transect was located off the shore by approximately one-third the distance between the shoreline and the point at which the dredging cut line surface meets the DoC. The long-shore transect was located at the approximate centroid of the wedge of sediments between the cut line and the DoC, and the samples collected along its length were in addition to the 40 locations in the remainder of the CU (GE, 2009b).

Post-dredging core locations assigned after the second dredging pass were located only in areas where inventory dredging was conducted. The post-dredging sampling grid was offset from the design support sampling grid used during the SSAP such that the post-dredging sampling points were located roughly 46 feet from the SSAP coring location, at the center of the triangle formed by 3 SSAP core locations. With similar sampling densities for both the SSAP and post-dredging core grids, the post-dredging coring program was designed to sample every other triangle formed by the SSAP grid. If obstructions were encountered at a collection point, the sample was relocated within a 20-foot radius of the original location at a point still within the area where inventory dredging was conducted. Post-dredging core collection points assigned after completion of additional dredging passes were located within 10 feet of the locations where cores were obtained during the first post-dredging sampling event. Sampling crews attempted to avoid precisely re-occupying previously sampled points (GE, 2009b) to avoid sampling a previously cored site.

The target penetration depth for post-dredging cores collected after the first dredging pass was four feet; if refusal was encountered above this depth, the core was advanced to refusal. Sections from the upper two feet were separated and submitted to the laboratory, where the 0-6 inch interval was analyzed and the remaining sample intervals up to 24 inches were archived by the laboratory. The remainder of the core was archived at the GE Hudson Falls facility for use in re-evaluating the DoC, as necessary, based on PCB levels observed in the 0- to 24-inch interval (GE, 2009b). Sample collection followed the methods presented below [as included in the RAM QAPP (GE, 2009b) and subsequent corrective action memos from GE to EPA]:

- Post-dredging cores were collected via vibracoring or manual coring techniques.
- Clear Lexan tubes were used for manual coring. When substrate conditions or water depths were such that manual coring was not feasible, cores were retrieved using vibracore techniques. Most cores were obtained by vibracoring.
- If vibracoring was employed, the rig was activated as the core barrel reached the sediment-water interface and used throughout the full depth of the core.
- Under conditions where a core could not be collected, samples were obtained using small ponar-type samplers (grab samples).
- Core collection nodes were located using GPS and referenced to the NAD 1983 State Plane horizontal coordinate system (in feet) and the NAVD88 vertical datum.
- Core identification information, sampling locations, and field data were recorded in GE's Sediment Residuals Sampling field database.
- Sediment probing was conducted in an adjacent location prior to core collection to identify the approximate thickness and texture of the sediments.
- Samples obtained from re-dredged nodes were collected as 0- to 6-inch core samples; sample collection methods were identical to those used for post-dredging cores collected after the first dredging pass.
- Design information and probing results were used to guide core collection although each coring attempt tried to collect 4 feet of sediment.

- Core recovery was measured upon collection directly through visual inspection of the sample and confirmed after extraction of the core during processing.
- Actual sample recovery was calculated by dividing the length of the sediment recovered by the total penetration depth of the core.
- The field team documented sediment recovery, visually classifying the sediment sample and the thickness of the residuals layer in the Sediment Residuals Sampling field database. Any additional information was recorded in a field log book.
- When probing indicated less than six inches of sediment over a hard material, at least one attempt was made to collect a core. A ponar grab sample was collected if a sediment core could not be obtained.
- If sample recovery was hindered by the presence of bedrock or an obstruction, up to three attempts were made to retrieve sediments using a coring approach within a 20-foot radius of the proposed sampling location. If that approach was unsuccessful, grab sample collection was attempted using a ponar-type dredge sampler for up to three additional attempts. Following such attempts, if sediment recovery was still not attained, presence of bedrock was noted at the location and sampling moved to the next sampling location.
- If a ponar dredge sampler was used, it was of sufficient size to penetrate at least six inches or the thickness of sediment believed present on the river bottom, whichever was less.
- Ponar samples were homogenized in dedicated, laboratory-decontaminated, stainless steel bowls, transferred to appropriately selected and labeled sample jars, and stored on ice in coolers until submitted for processing and analysis
- After collection, the core was capped, sealed, and labeled. Labels included core identification information, date, time, and an arrow to indicate the upper end.
- The cores were transported with river water in the headspace to minimize disturbance of the top core layer.
- The cores were stored on ice in a storage rack in a vertical position and kept in the dark until submitted for processing and analysis.

As per the RAM QAPP, post-dredging sampling in a CU was to be completed within seven days of the completion of each dredging pass in that CU. Each CU, however, was divided into subunits. If the active dredging was downstream of completed subunits, then residual samples could be collected from the completed subunits of the CU prior to the completion of dredging in the entire CU.

4.10 Evaluation of the Residuals Sampling Locations

Based on evaluation of the post-dredging core sample spacing implemented during Phase 1, the Residuals Standard was adhered to with only a few exceptions with little, if any, impact on the overall compliance with the standard, as described below. As per the Standard, at least 40 locations must be sampled in each CU on a triangular grid after finishing the first dredging pass. To maximize the spatial distribution of these samples, locations were selected such that each post-dredging core falls in the center of an 80-foot triangle formed by the SSAP cores. Due to this positioning, the average distance between the SSAP core locations and the post-dredging residuals cores is approximately 46 feet.

A total of 943 locations were sampled in the 10 completed CUs during Phase 1 to comply with the Residuals Standard. Of these locations, 64 were sampled in near-shore areas where the design dredging cut lines were shallower than the DoC because of slope stability concerns. The remaining 879 locations were sampled offshore. Of the 943 locations, 73 were abandoned due to the presence of rock, sand, gravel, or wood debris. Attempts were made to collect samples in 27 of the 73 abandoned core locations after subsequent dredging passes. Samples were successfully collected in 17 of those 27 attempted locations. 24 of the 73 locations were abandoned after the first dredging pass and remained abandoned for all dredging passes. These locations are identified in Figure II-4.9-1.

The Residuals Standard allowed sampling locations to be relocated within a 20-foot radius of the originally planned location if obstructions such as bedrock were encountered or if the estimated thickness of the sediment (via probing) was less than 6 inches. The impetus to obtain a sample can potentially lead to the inadvertent placement of first pass post-dredging cores outside the 20-foot radius requirement to maintain a midpoint between SSAP cores, and subsequent sampling locations may not meet the 10-foot radius requirement around the first node. To evaluate the sampling grid's adherence to the Residuals Standard requirements, the following steps were taken:

- Post-dredging core locations for all dredging events were compared with the SSAP core locations.
- Locations sampled after subsequent dredging passes were compared with locations sampled after the first dredging pass.

The results of these evaluations are provided below.

4.10.1 Comparison of the SSAP Core Locations and the Post-Dredging Core Locations

The standard required that the 40 or more post-dredging cores per CU be located midway between the SSAP cores, as described above. Evaluation of the first pass post-dredging cores shows that 40 or more locations were sampled in each of the 10 CUs that were dredged in Phase 1, as required. The post-dredging sampling locations were correctly placed on an 80-ft triangular grid and the locations of the nodes were approximately 46 feet away from the SSAP cores, meeting the average spacing required by the standard. The post-dredging sampling locations and the SSAP core locations are shown in Figure II-4.9-1.

4.10.2 Comparison of Post-Dredging Core Locations after Each Dredging Pass

The Residuals Standard required that after each subsequent dredging pass, post-dredging cores be collected within 10 feet of the sampling locations for the initial dredging pass. Adherence to this requirement was evaluated and it was found that the majority of the coring locations were compliant. Given the sub-meter accuracy of the GPS, locations within approximately13 feet of the initial sampling locations were judged to have met the requirement of the standard. Only 15 of the 410 cores collected after second or subsequent dredging passes exceeded this tolerance. These 15 cores, sorted by their distances from the original residual sample location, are listed in Table II-4.9.2-1.

Of these 15 cores, 7 were moved because of the offsets in dredging approved by EPA (these cores are highlighted on Table II-4.9.2-2). These include three cores in CU-2 (at locations SRN-CU002-041, SRN-CU002-042, and SRN-CU002-043) for which EPA had requested a 10-ft. offset from the 119-foot elevation contour line due to the presence of timbers having archaeological significance. One core in CU-4 (at location SRN-CU04-32) was moved because of the archaeological significance of the historical remains of an old boat manufacturing facility located at the southern tip of Rogers Island. In CU-1, a core at location SRC-CU01-13 was offset at the request of the New York State Canal Corporation (NYSCC) in front of the Yacht Basin wall. Finally, due to dredging of a sand bar located in CU-8, two cores at location SRN-CU008-045 were relocated from the edge to the center of the sand bar. According to field staff, the remaining 8 core locations were likely offset due to errors in GPS coordinates given to sampling crews. These locations all occur in CUs 1, 5 and 8. Core SRC-CU005-FR000022 is the only one of these locations where bedrock was encountered. The number of locations out of compliance is small and of little consequence.

4.11 Analytical Methods

4.11.1 Modifications to Method GEHR8082 for Post-Dredging Core Samples

Post-dredging sediment samples were extracted and analyzed for Target Compound List (TCL) PCB Aroclors and Total PCBs using Method GEHR8082 and for moisture content using ASTM D2216-98. The PCB target method detection limit (MDL) for the sediment residuals samples was 0.05 mg/kg, with a reporting limit (RL) of 0.1 mg/kg for each PCB Aroclor. In addition, a second PCB analysis for Congeners was conducted on 4 percent of the samples using the Modified Green Bay Method (mGBM). It was intended that the mGBM analyses be “front loaded" (*i.e.*, conducted more frequently at the beginning of the program), with a target of 15 to 25 percent of samples (GE, 2009b). A discussion of the actual percentage of 2009 Phase 1 residual sediment samples analyzed using the mGBM is included below.

The analytical procedures for the preparation and analysis for TCL Aroclors and Total PCBs used during the Remedial Action Monitoring Program (RAMP) were the same as those developed for the SSAP so that the data collected during the RAMP would be comparable to that obtained during implementation of the SSAP; however, the following modifications were made to the procedures in order to achieve lower RLs:

- Lowering the final extract volume from 25 mL to 10 mL; and
- Increasing the sample weight from 10 grams to 20 grams.

The RAM QAPP anticipated that the combined modifications would result in an approximately five-fold increase in sensitivity and would address the moisture content of the majority of the samples in that a RL of ≤ 0.1 mg/kg for each PCB Aroclor was achieved for samples with moisture contents as high as 90 percent (based on the unadjusted RL of 0.01 mg/kg). The distribution of the moisture content of all environmental sediment samples collected during the SSAP indicates that very few samples had moisture contents greater than 90 percent. Although these modifications had the potential to concentrate matrix interferences in addition to concentrating the target analytes, it was expected that the same cleanup procedures utilized during the SSAP were sufficient for the RAMP, as little to no interferences were observed during the SSAP. The initial sediment residual sample chromatograms were examined to confirm the effectiveness of the sample preparation and cleanup procedures during the laboratory audit performed while the samples from the first CU were at the laboratory (GE, 2009b).

Additional modifications included adjustment of surrogate spike concentrations to account for the increased sensitivity, and the following changes for the laboratory control sample (LCS):

- An LCS consisting of Aroclor 1221 and Aroclor 1242 at a ratio of 3:1 (instead of only Aroclor 1242, as has been used for the SSAP) was prepared and analyzed with each batch of samples. The Aroclor 1221 and Aroclor 1242 concentrations were approximately 0.75 mg/kg and 0.25 mg/kg, respectively, for a Total PCB concentration of approximately 1 mg/kg instead of 1.25 mg/kg that was used during the SSAP.

- Accuracy acceptance limits were established at 50 to 150 percent recovery for each Aroclor. If the accuracy limits were not met for either Aroclor, sediment samples associated with the LCS were re-extracted and reanalyzed.

The RAM QAPP anticipated that these modifications to the LCS would provide a quality control analysis in a pure matrix for both Aroclor 1221 and Aroclor 1242 in a ratio representative of Hudson River sediments (GE, 2009b). At the time of the preparation of this report, EPA had not yet received affirmation as to the success of these changes.

4.11.2 Comparison Between Method GEHR8082 and Modified Green Bay Method for Post-Dredging Sediment Samples

EPA is still evaluating this information and will continue discussions with GE on this topic.

5. Evaluation of Re-dredging of Non-compliant Areas and Instances where Sediment Inventory was Capped

This section evaluates the process used to determine the areal extent of re-dredging areas during Phase 1, summarizes instances in Phase 1 where contaminated sediment inventory was left in place, and reviews the Phase 1 CU closure experiences, including the construction of sub-aqueous caps to isolate contaminated sediment.

The Residuals Standard required that re-dredging areas be determined by calculation of a 'non-compliant area' or NCA. EPA's check on GE's calculations of the NCA revealed that GE arrived at slightly smaller areas for re-dredging than by using the method required by the Residuals Standard. It is not clear how GE arrived at the NCA, although they may have used a method based on Thiessen polygons. Further information is provided in Section II-5.1 below.

Evaluation of the spatial correlation between post-dredging core samples revealed a very weak correlation (refer to Section II-5.2). Given that there is little spatial correlation in the post-dredging data and that there are questions regarding the preparation of NCA, it is appropriate to extend the NCA to the location of adjacent, compliant nodes rather than trying to interpolate boundaries between nodes. In addition, the need to minimize time between dredging passes supports the selection of a straightforward method for development of NCA.

Section II-5.3 identifies the mass of PCB inventory left undredged in each CU and identifies locations where dredging efforts did not reach the depth of the design cut line, but were completed at a shallower elevation. Section II-5.4 provides a summary of CU closure in Phase 1.

5.1 Evaluation of the Non-Compliant Area

5.1.1 Methodology

The extent of Non-Compliant Area (NCA) around a particular post-dredging core location is determined by linear interpolation between two neighboring core samples by the following equation, which is given in Section 4.5.5, Determining the Extent of the Non-Compliant Area, of the Engineering Performance Standards, Technical Basis and Implementation of the Residuals Standard, Volume 3 (USEPA, 2004). The calculation is based on Tri+ PCB concentrations at each node.

$$d_r = \frac{d \times (C_1 - C_3)}{(C_1 - C_2)} \qquad \text{(Equation II-5.1.1-1)}$$

where:

d_r is the distance to re-dredge from node C_1 towards C_2.

d is the distance between the elevated and compliant nodes.

C_1 is the Tri+ PCB concentration at the elevated node under consideration.

C_2 is the Tri+ PCB concentration at a compliant node surrounding node C_1.

C_3 is the desired Tri+ PCB concentration at the area boundary (1 mg/kg).

If d_r is less than half of the distance between nodes, the distance to define the NCA is, in accordance with the standard, half of the distance between nodes. C_3 is always 1 mg/kg Tri+ PCBs, which is the desired average concentration. By applying the above equation, the boundaries of a hexagon where the concentration is greater than 1 mg/kg Tri+ PCB are delineated (see Figure II-5.1.1-1 as an example). The NCA is then bounded by the 1 mg/kg Tri+ PCB concentration contour lines perpendicular to the axes between the sampled nodes. The NCA should not extend beyond the boundaries created by connecting the surrounding nodes. If the node is next to a CU boundary, the NCA should follow that boundary.

There are two major processes performed to determine the extent of the NCA. The first is a statistical analysis which determines whether a sampled node needs to be included in the NCA process. The second process involves delineating the boundaries of a NCA using the formula above and a computer-based design package.

For the first statistical process, if the median value of the concentrations in a given CU is greater than or equal to 6 mg/kg Tri+ PCB, the entire CU will be a NCA. On the other hand, if the mean value is greater than 1 mg/kg Tri+ PCB but the median value is less than 6 mg/kg Tri+ PCB, a moving average is used to determine whether some particular sampled nodes may be excluded from re-dredging. The residual core concentrations are sorted and placed in ascending order.

The mean value is then calculated for the entire set of nodes in the CU, nominally, 40 values. Beginning with the highest value, a value of 0.024 mg/kg Tri+ PCB (the detection limit value) is substituted for the detected value and the mean of all nodes is recalculated. This process is repeated, substituting 0.024 mg/kg for the highest remaining value and working down the list of ranked values, until the mean of the modified set of results drops to 1 mg/kg Tri+ PCB rounded to a whole number (effectively 1.49 mg/kg). Upon reaching 1 mg/kg Tri+ PCB, all nodes that were substituted with 0.024 mg/kg are considered non-compliant and are used to define the NCA. The actual concentrations for the non-compliant nodes are used for the second process.

For the second process, the nodes identified in the first process are used to estimate 1 mg/kg contour lines around the NCA using the formula above. In all cases, the boundaries are drawn based on perpendicular lines connecting compliant and noncompliant nodes, as stated in the Residuals Standard. Although it is not known for certain, it is apparent from the maps provided by GE that Thiessen polygons were used to aid the determination of the NCA boundaries, although this is not called for in the Phase 1 supporting documents.

5.1.2 Results

The NCA for CU-18 derived using the methodology presented above by EPA (3.7 acres) is about 4 percent larger than the area derived by GE's Method (3.55 acres). While a small difference relative to the overall area, the GE method ultimately left areas unaddressed that are likely to exceed the removal criterion. The results show that using the methodology presented above yields larger NCA area. For the purpose of comparison, the NCAs calculated by GE were digitized from the pdf figures.

As an example, Figure II-5.1.2-1 compares the NCA derived by GE and EPA in CU-18. Again, these figures show larger areas derived by the Residual Standard method described above. Figures II-5.1.2-2 and II-5.1.2-3 illustrate the differences in further detail. NCAs derived by EPA ensure that the non-compliant areas extend to the 1 mg/kg contours as specified by the standard, whereas those derived by GE do not always extend to the 1 mg/kg contour lines.

At each of these locations in CU-18 as well as in some other CUs, the NCAs derived by EPA extend to the 1 mg/kg contours as defined by Equation II-5.1.1-1 above, whereas those derived by GE do not. At these locations the GE-defined NCA is smaller than required by the standard and there is the potential that PCB-laden sediment that should have been targeted for dredging may have been left in place. Because of the need to respond quickly to field conditions, there was insufficient time for EPA to redraw the boundaries originally proposed by GE to the exact requirements of the Standard. Instead, EPA and GE redrew the boundaries manually and minimized the disruption to the operations while also capturing the majority of sediments of concern in the area. For example, in CU-7, EPA instructed GE to extend the boundaries closer to the compliant nodes (indicated by the magenta outlined-boxes in Figure II-5.1.2-4).

Because of the differences and difficulties in implementing the boundary definitions in Phase 1, it is recommended that the process of constructing re-dredging boundaries should be simplified and streamlined for Phase 2. For locations where a single non-compliant node is surrounded by compliant nodes, the non-compliant node should be dredged to the periphery as defined by the compliant nodes. For locations where a compliant node is surrounded by non-compliant nodes, the area associated with the compliant node should be dredged to the average depth of the surrounding non-compliant nodes. No area should be excluded based on a single compliant node. Three compliant nodes should be required to define an area that does not require re-dredging. These steps will eliminate the more sophisticated algorithm developed for Phase 1 that was a source of much discussion and often resulted in intricate dredging geometries. In support of this recommendation, it should be noted that the Phase 1 boundary definition process was predicated on a well-defined DoC surface as well as the existence of spatial correlation in the data. The lack of a robustly-determined DoC in Phase 1 and the lack of spatial correlation in the post-dredging core data argue in favor of conservative sediment removal.

5.1.3 Current NCA Requires Modification due to Shifts in Re-dredging 'Footprint'

During Phase 1, in the process of identifying compliant and non-compliant nodes according to the criteria in the Residuals Standard, an unexpected occurrence was observed on a number of occasions. Specifically, nodes that were identified as compliant on a particular dredging pass became non-compliant on a subsequent dredging pass. This resulted from incomplete removal of contamination from non-compliant nodes during re-dredging, followed by a re-ranking of the nodes in the CU (according to PCB concentration) after the next round of post-dredging core sampling. This had the potential to result in observed changes in the location and extent of the dredging or capping areas in a particular CU from pass to pass ('shifting footprint'), as described below.

Figure II-5.1.3-2 illustrates an example of the shift in dredging footprint in CU-17 for Core SRN-CU17-0030. After the first dredging pass, the median Tri+PCB surface concentration of the post-dredging cores was less than 1 mg/kg, requiring re-dredging of only non-compliant nodes. Eleven nodes were classified as non-compliant based on the thresholds in the Residuals Standard and were selected for re-dredging. The average Tri+PCB surface concentration of the compliant nodes was 1.32 mg/kg. Core SRN-CU17-0030, with a surface Tri+PCB concentration of 13 mg/kg was classified as compliant and did not require re-dredging.

The average Tri+PCB concentration of CU-17 after dredging pass 2 was 4.26 ppm. Due to the concentrations detected in the post-dredging core samples, core SRN-CU17-0030 was now classified as non-compliant and required re-dredging. Hence the dredging 'footprint' shifted between re-dredging passes. Since only one six-inch slice of this core had been analyzed, the area of influence of this core was dredged using the DoC of the neighboring non-compliant cores.

A second example for CU-04 is provided in Figure II-5.1.3-1. In this instance, the two nodes that switched from compliant to non-compliant during the various passes ultimately affected the lateral extent of the cap constructed over the non-compliant area. The switching of the nodes added to the time required for engineering design of the cap, since the cap had to be extended over these nodes that were initially compliant.

The concern regarding a shifting dredging footprint is that additional complexity is introduced into the design of subsequent dredging passes. It is preferable that response actions (*e.g.*, dredging, capping) continue within the area identified as non-compliant after the initial dredging pass until the CU is closed in compliance with the Residuals Standard. There is a concern that by allowing shifting of the dredging footprint between passes, the nodes that are contributing most significantly to non-compliance are not being fully remediated.

5.2 Geostatistical Evaluation of Residuals Data for Spatial Correlation

The post-dredging core data was tested to investigate whether there is spatial correlation among sample locations. This is important because many of the decisions made using the sample data assume that there is a correlation at the distances sampled. This is especially true for the decision to dredge at a weighted distance between a sample location where PCBs were detected and a location where they were not. If there is no spatial correlation between samples, then there is no basis to interpolate and the only technically defensible alternative is to dredge entirely to the location of the compliant sample. The analysis found that at a spacing of 80 feet there is, at best, a weak spatial correlation. Based on the findings of this analysis, the simplest method to deal with weak spatial correlation without increasing sampling density is to requiring dredging up to compliant nodes (*i.e.*, allowing no weighted interpolation of the dredging boundary between compliant and non-compliant nodes).

The spatial correlation of post-dredging core samples was tested by preparing semivariograms of 0 to 6-inch Tri+ PCB and Total PCB data collected after the first dredging pass. Semivariograms ($\gamma(h)$) are calculated using the formula:

$$\gamma(h) = \frac{1}{2N}\sum_{i=1}^{N}\left(f_{1i}-f_{2i}\right)^2 \qquad \text{(Equation II-5.2-1)}$$

where N is the number of samples within the lag distance, and f_{1i} and f_{2i} are the values of two points that are separated by the lag distance (within the lag tolerance). For spatially-correlated data, the variogram value (the value calculated for a specific lag in a semivariogram) generally increases and approaches the sample (theoretical) variance the further the points in the data pairs are from each other (the larger the lag). When the variogram value reaches approximately the sample variance (at a point referred to as the sill), there is no spatial correlation beyond that distance. By creating a semivariogram from the collected data, the ability of the sample grid to estimate the CU residual concentration is tested: if there is spatial correlation for a distance greater than the sample grid spacing, then the grid can be used to characterize the spatial variability.

The lag spacing used for the variogram analyses was 80 feet, which is roughly equivalent to the sample spacing employed during post-dredging sampling. A lag tolerance of half the lag spacing, 40 feet, was used so that all data are included. The resulting variogram values were divided by the sample set variance to normalize the variogram for comparability amongst data sets and to test the relationship of the variogram value to the variance; see Table II-5.2-1. When evaluating the variogram at the distance of the sample spacing (80 feet) the value of the variogram divided by the variance shows the amount of variance that is not correlated between samples, *i.e.*, the percentage of the sample set variance. The reverse is also true: 1-(variogram/variance) represents the amount of correlation between samples at the lag distance. If the variogram/variance value approaches or is greater than 1, then there is no spatial correlation at that distance.

From the table it can be seen that only CUs 2, 6 and 17 have reasonable spatial correlation in either the natural data set or the log-transformed data set at a spacing of 80 feet. For CUs 3, 4, 8 and 18, the log-transformed data are more spatially correlated; however, these spatial correlations are weak. Except at CU-6, the log-transformed data are generally more correlated than the natural data.

If a reasonable variogram is created by the data set, it can be used to assess the nugget (random variability) that can be expected in co-located samples. This would be represented by the value of the variogram at the y axis. Figure II-5.2-1 shows variogram/variance plots for each of the CUs. In most cases, only the 80-foot lag interval falls below the population variance and so a projection to 0-feet of separation is not possible. At CU-2 the projected nugget is about 70 percent of the population variance, at CU-6 it is between 40 and 55 percent, and at CU-17 it is between 35 and 70 percent of the population variance. More-closely spaced data are needed to refine the estimation of nugget at all of the CUs. It is possible that at closer spacing the data will become more strongly correlated than predicted; however, from the analyses conducted, the nugget appears to be a significant portion of the population variance and thus any individual sample value has a high degree of uncertainty. The Residuals Standard indicated that the spacing of post-dredging cores would be re-evaluated after Phase 1. While there is not a sufficient basis to recommend more closely-spaced post-dredging cores, no requests to relax the spacing (samples more distant than 80-foot centers) should be accepted due to the weak spatial correlation.

5.3 Areas where Contaminated Sediment Inventory was not Dredged

5.3.1 Calculation of Remaining Inventory by CU

Table II-5.3.1-1 presents a calculation of the contaminated sediment inventory left undredged in each Phase 1 CU. According to the standard, the goal of the remediation is to remove 96 to 98 percent of the PCB inventory. Phase 1 dredging was successful in removing approximately 92 percent (98 percent if CU-1 is excluded) of the inventory that was identified by the post-dredging and SSAP cores; however, this was accomplished over 3 to 4 dredging passes, with adverse impacts to productivity and perhaps to resuspension.

For all CUs except CU-1, the mass of the remaining inventory was calculated using the average TPCB concentration in a six-inch interval and associated volume in that interval. For CUs where bedrock was observed, mass was calculated only in the non-bedrock areas. Cores falling in the bedrock areas are excluded from the average concentration calculations. For CU-7, where clay is observed in the majority of the area, it is assumed that the concentration of the post-dredging cores accounts for the presence of clay.

For CU-1, averaging the concentration of the post-dredging cores sampled after Dredge Pass 5 and the volume estimated from the elevation of the test pits was used to calculate the mass of inventory left behind. Note that the volume accounts for the presence of bedrock encountered in CU-1.

5.3.2 Shoreline Areas Where Design Cut Lines Were Not Met

In general, the dredging operations met the design cut lines for each dredging pass. Areas where the design cut lines were not met were largely limited to shoreline areas. It is unclear why this pattern developed, but it may be due to imprecision in bathymetric measurements, difficulty in access, and unique design requirements (slope stability) associated with shoreline areas. An examination of this issue will be provided in an Appendix to be submitted in April 2010.

5.4 Summary of the CU Closure Process

Removal of PCB-contaminated sediments from specific CUs was intended to proceed to a depth corresponding to an uncontaminated surface and to be considered complete when PCB concentrations in post-dredging (residuals) samples met the criteria described in the Residuals Standard. Based on the Residuals Standard criteria, field decisions were to be made as to whether to continue dredging, place backfill, or place an engineered cap. Capping was the remedy of last resort and to be employed only when dredging failed to remove the PCB-laden material to concentrations within the Residuals Standard criteria. Once dredging was complete and either backfill or an engineered cap was placed, the CU was considered closed.

In Phase 1, dredging was planned in 18 CUs. While dredging was initiated in 12 of these 18 CUs, only 10 CUs (CU-1 through CU-8, CU-17, and CU-18) were considered closed at the end of the 2009 navigation season. Although minimally initiated, dredging was not performed to completion and closure activities were not conducted in CU-9 and CU-12 due the unexpected amount of dredging required at the other CUs.

After the analysis and evaluation of post-dredging core samples, the remaining sediments in each CU were re-dredged, backfilled, or capped, depending on the response action criteria established by the Residuals Standard and as modified in the field with EPA's concurrence. After the various response actions were completed, the 10 CUs where significant dredging took place were considered closed, although varying amounts of inventory were left in place.

The results of dredging and sampling were detailed in the CU *Dredging Completion Approvals Form 1's* and submitted to EPA. These results were used to determine the next action, whether further dredging, backfilling, or capping, that would be performed in a CU. Form 1's provide details on each CU's dredging activities, including the dredging timeframes, number of samples, average/median/mode PCB concentrations, the number of 'inventory' and 'residual' dredging passes, sediment types encountered, summary of non-compliant nodes within the CU, and a list of EPA/GE field agreements specific to the CU. The signed Form 1 for each CU represents the closure of the dredging stage of remedial activities at each CU. Completed copies of Form 1's for all closed CUs are provided in Appendix II-D.

The results of the backfill and capping activities were detailed in the *CU Backfill/Engineered Cap Completion Approvals Forms 2* and submitted to EPA. Form 2's detailed each CU's backfill (Type 1 or Type 2) or cap materials (Type A or Type B, and low to high velocity), installation timeframes, summary of placement operations, and a list of EPA/GE field agreements specific to the CU. The approved Form 2 for each CU validates the second stage of remedial activities and, coupled with the approved Form 1, completes the CU closure effort. Completed copies of the Forms 2 from backfilled and capped CUs are provided in Appendix II-E. There are also Form 3's that describe habitat restoration that will be completed in the future.

Capping was performed in 9 of the 10 closed CUs (excluding CU-17). Of the capped areas, sediments were left behind that contained more PCBs than permitted by the ROD or the Residuals Standard in CU's 1, 2, 4, 5, 6, 7, and 8. At CU-1, nearly 100 percent of the area was capped, with the underlying sediments exceeding the Residuals Standard. Dredging in CU-1 was not completed because more dredging was required in that CU than expected and the schedule was constrained by the end of the navigation season. Backfill was placed in most areas that were not capped, except small parts of the navigation channel in CU-2 and CU-17.

Additional details regarding CUs that met the 1 mg/kg threshold, CUs requiring engineered caps, CUs requiring shoreline caps, and treatment of shallow bedrock at various CUs are provided in the sections that follow.

5.4.1 Subaqueous Capping Necessary to Address Missed Inventory, Navigation Season Constraints, and Difficult Dredging Conditions

A remedial goal of this project was removal of 96 percent to 98 percent of the PCB-contaminated sediment inventory (USEPA, 2002). Review of the case study data has shown that, generally, this level of removal has been achieved at other sites, some with more difficult environmental conditions than those expected in the Upper Hudson River (USEPA, 2002). Even so, to avoid multiple dredging passes in instances where inventory has been removed but residual concentrations are unacceptable, subaqueous capping was allowed. Capping performed under the Residuals Standard was not intended to sequester significant PCB inventory. Capping is less reliable for long-term control than dredging, and there are long-term operation and maintenance requirements associated with capping.

With the exception of CU-17, some portion of all CUs dredged during Phase 1 was capped. The intent of the capping response defined in the standard was to provide an option to manage CUs with Tri+ PCB concentrations greater than 1 mg/kg but less than 6 mg/kg or where re-dredging attempts to reduce more elevated concentrations were unsuccessful after two attempts. It was expected that this would occur in areas with rocky bottoms or conditions otherwise difficult to dredge; however, it also occurred unexpectedly in areas where previously uncharacterized inventory was encountered. The second case is not related to dredging residuals and was not a condition that was expected to drive multiple dredging passes once the Residuals Standard was implemented for a CU. That said, the Residuals Standard performed reasonably well in managing the dredging of missed inventory, which was a site characterization and dredging design shortcoming. Another factor that contributed to the need for capping was a time constraint associated with the end of the navigation season; in some CUs, further dredging could not be completed to meet the canal closing schedule. If time was not a constraint, less area would have needed to be capped.

Subaqueous caps were installed in 9 of the 10 CUs closed in Phase 1, covering 36 percent of the total CU area dredged (17.3 of the 48.2 acres). The acreage capped in each CU is presented in Table II-4.1-1a. The comparison shown on Figure II-5.4.1-1 indicates that the acreage capped in a CU generally increases as the proportion of cores indicating the presence of missed inventory increases. Conditions like those on the east side of Rogers Island are unlikely to be encountered in Phase 2. If the east side of Rogers Island was removed from the evaluation, the actual capping required in the remaining CU's (5, 6, 7, 8, 17, and 18) is closer to 19 percent (5.8 acres out of

30.3 acres total), based on information presented in the CU Completion Form 1s. Of the 5.8 acres of caps placed in these CU's, approximately 3.16 acres were covered by at least 2 feet of backfill and brought up to the photic zone, thus allowing for potential planting and habitat benefits. The remaining approximately 2.64 acres of cap placed in these areas represent approximately 8.7 percent (2.65 acres) of the total area capped (30.3 acres - without the area associated with the east side of Rogers Island) and is not inconsistent with the what the standard envisioned for capping.

5.4.2 20-Acre Joint Evaluation

The Residuals Standard allowed for CUs with an arithmetic average residuals concentration greater than 1 mg/kg Tri+ PCBs and less than or equal to 3 mg/kg Tri+ PCBs to be jointly evaluated along with previously dredged CUs within two miles of the CU under evaluation. If the area-weighted arithmetic average of a 20-acre area (4 CUs) was less than or equal to 1 mg/kg Tri+ PCBs, backfill could be placed with subsequent testing to confirm compliance with the average post-remediation surface concentration anticipated by the ROD (*i.e.*, ≤ 0.25 mg/kg Tri+ PCBs). This option was intended to provide flexibility in addressing CUs that were slightly non-compliant. The 20-acre evaluation was not performed during Phase 1, primarily due to the high number of CUs that were capped, and therefore its utility cannot be evaluated. Because it was not used during Phase 1, it is recommended that this option be eliminated from Phase 2 to simplify the Residuals Standard.

5.4.3 Backfill Testing

Backfill testing was not conducted during Phase 1 (refer to Section II-5.4.2 above). This action was required by the Residuals Standard only as part of the 20-acre joint evaluation process. Elimination of this evaluation from the Residuals Standard will also remove any requirement to test backfill placed post-dredging.

5.4.4 Certification Units Achieving the 1 mg/kg Tri+ PCBs Threshold

The Residuals Standard requires that Tri+ PCB concentrations in the 0-6 inch sediment depth at post-dredging core locations within a CU average less than 1 mg/kg and that no PCB inventory be found in all segments analyzed below six inches. Of the 10 CUs that were closed during Phase 1, only CU-17 achieved the 1 mg/kg threshold. A total of three dredging passes were performed at CU-17. No non-compliant post-dredging cores were identified after the last dredging pass, resulting in backfill treatment over the entire 4.99 acres, except in the navigation channel.

Dredging at the remaining 9 CUs did not reduce residual Tri+ PCB concentrations below the standard's criteria; therefore, engineered caps (a contingency action) were installed over some portion of each of these 9 CUs to address remaining inventory. Between 3 and 5 dredging passes were performed prior to capping in each of these 9 CUs, with final average Tri+ PCB concentrations in the 0 to 6-inch segments prior to capping ranging from 2 mg/kg in CU-3 to 29 mg/kg in CU-1. The primary factor affecting the inability to achieve the 1 mg/kg threshold was the inadequately determined DoC.

A summary of the details for each CU, including the number of dredging passes, the number of initial and final nodes sampled, the percent decrease in post-dredging samples collected, and average and median Tri+ PCB concentrations, is provided as the Summary of CU Dredging in Table II-5.4.4-1.

5.4.5 Certification Units Requiring Caps for Residuals

The Residuals Standard specifies a series of required actions based on Tri+ PCB concentrations observed in post-dredging cores. Subaqueous capping is one of the contingency actions specified in the standard. As per the Residuals Standard, a cap was permitted to be placed in a CU if at least two residuals dredging passes had been attempted, the mean Tri+ PCB concentration in the uncapped area of the CU was less than 6 mg/kg, not more than one sample reported Tri+ PCB concentration greater than 15 mg/kg, and no samples reported Tri+ PCB concentrations greater than 27 mg/kg. The intent of cap placement during the Phase 1 activities was to isolate concentrations of Tri+ PCB in "residual" sediments – comparatively thin layers (about 6 inches or less) with elevated Tri+ PCB concentrations that were not successfully removed after multiple dredging attempts (for example, in bedrock areas). The basis for this element of the standard assumed that the complete DoC of the CU had been established and that a "true" residuals dredging pass had been conducted (*i.e.*, one where only sediments spilled or dislodged but not captured during the previous dredging pass needed removal). The capping option in the Residuals Standard was not intended to sequester inventory material.

Partial caps were constructed in 8 CUs to address non-compliant nodes (CU-2 to CU-8, and CU-18), ranging in size from 0.88 acres in CU-5 (18 percent of the CU area) to 3.56 acres in CU-4 (79 percent of the CU area). A cap was installed over the entire area of CU-1 (3.39 acres). Table II-3.4.2 summarizes nodes that were capped during Phase 1 dredging.

The number of non-compliant nodes ranged from 3 in CU-18 to 41 in CU-1. In six of the eight CUs that were capped, the average Tri+ PCB concentrations of the capped nodes exceeded 27 mg/kg and more than 1 node contained Tri+ PCB concentrations greater than 15 mg/kg. For 3 CUs (*i.e.*, 1,2, and 8), a cap was placed after the last dredging pass even though the average Tri+

PCB concentration in the CU was greater than 6 mg/kg. The decision to place a cap in CUs 1, 4, and 8 was approved by EPA because further dredging could not be implemented due to impending closure of the navigation season.

- GE dredged CU-1 from June 4, 2009 to October 27, 2009 and removed an average of 6 feet of sediment. The presence of contaminated wood debris, which extended to an estimated depth 3 feet below the final dredging cut elevation, coupled with the end of the navigation season, prevented GE from completing the dredging of non-compliant sediment.

- GE dredged CU-4 from July 16, 2009 to October 26, 2009. Closure Case H of the Residuals Standard was achieved at this CU.

- GE dredged CU-8 from July 21, 2009 to October 24, 2009 and achieved Closure Case H.

For CU-6, the decision to cap 2 nodes with Tri+ PCB concentration greater than 27 mg/kg was made due to the presence of bedrock in the vicinity of the two nodes that made further dredging difficult. For CU-5, the decision to cap the three nodes was associated with a recalcitrant area, specifically a deep ‘hole’ that was going to require multiple feet of cover material and a surface shape that was very difficult to dredge. This deep hole was later covered with several feet of backfill. The decision to cap one node with Tri+ PCBs greater than 27 mg/kg in CU-7 was approved due to the presence of clay in the vicinity of this location that made dredging difficult.

Some of the nodes capped in these CUs did not have a DoC established; PCB concentrations greater than 1 mg/kg were still reported in the core sample segments below 6 inches. These cores are classified as inventory nodes. The percentage of inventory nodes capped during Phase I dredging is reported in Table II-3.4.2. The percentage of capped inventory nodes during Phase 1 dredging ranged from 45 % in CU-4 to 100 % in CU-1. This problem is expected to be resolved for Phase 2 with refinement of the DoC and overcutting recommendations (design modifications) and some adjustments to the Residuals Standard. Also, capping due to schedule constraints is expected to be minimized in Phase 2 as the full extent of dredging required becomes better quantified.

5.4.6 Certification Units with Shoreline Caps

The PSCP states that the maximum depth of cut at the shoreline is 2 feet. This limitation was enacted to prevent possible destabilization of the shoreline. The PSCP also states that if the DoC at the shoreline is greater than 2 feet, a 2-foot cut with a vertical side slope should be made at the 119-foot contour line and the cut line should then proceed downward into the river at a slope of

3H to 1V (or existing steeper slope if stable) until the full depth of contamination is reached. Limiting the dredging depth to 2 feet at the shoreline in areas where contamination extended below that level would potentially leave a small wedge of contaminated sediment behind. GE was required to test the remaining sediments and remove all shoreline sediments with a 50 mg/kg or higher Total PCB concentration. This could require a deeper than 2 foot cut at the shoreline, if necessary.

Fifty-seven shoreline cores were collected in 32 locations. Table II-5.4.6-1 provides a summary of the shoreline cores collected during Phase1 dredging.

Of the 57 shoreline cores, 43 (or 75 percent) contained Total PCB concentration greater than 1 mg/kg, and 17 of those (or 29 percent) contained Total PCB concentrations greater than 50 mg/kg (one core located in CU-2 that contained a Total PCB concentration above 50 mg/kg was not capped). Shoreline cores containing Total PCB concentrations greater than or equal to 1 mg/kg ranged from 33 percent (CU-1) to 100 percent (CU-7), and cores containing Total PCB concentrations greater than or equal to 50 mg/kg ranged from 20 percent (CU-3) to 57 percent (CU-7). Shoreline caps were installed at 5 of the 9 CUs where full or partial engineered caps were employed (CU-1, CU-2, CU-3, CU-7, and CU-8).

Of the 32 locations where shoreline cores were collected, twelve shoreline core locations were capped during Phase 1, with the majority of the caps placed in accordance with the Residuals Standard. Caps were placed over locations with Total PCB concentrations exceeding 50 mg/kg at two shoreline core locations.

Based on experience from Phase 1, the vertical shoreline depth of cut and Residuals Standard attainment review process should be refined. Specifically, a grid size and shape that is more sensitive to potential sediment slumps and small variations in the core locations at shoreline vertical cuts is needed. The 10 ft x 10 ft cell size used in Phase 1 is too large to reflect lack of attainment of depth of cut at shorelines and must be reduced to a 1 ft x 1 ft grid.

5.4.7 Treatment of Certification Units with Shallow Bedrock Areas

During Phase 1 dredging, dredge bucket refusals due to the presence of bedrock and boulders were encountered at various locations in each of the 10 completed CUs. The extent of refusals ranged from approximately 0.06 acres in CU-7 to approximately 3.9 acres in CU-6.

There were areas where bucket refusal was encountered at a depth shallower than either the design DoC or the DoC estimated from the post-dredging core data. These were generally locations where bedrock or boulders presented an uneven surface and cores had been collected from locations where sediments were thickest or where the DoC was projected from incomplete cores. Because an uneven surface was encountered and the bucket refusal was above the estimated DoC, some inventory is presumed to remain in these areas (although in the context of this project the volume of this inventory is comparatively small). The impacted acreage in the 10 CUs ranged from none in CU-17 and CU-18 to 1.5 acres in CU-6.

The largest areas of bedrock were encountered in CU-5, and the depth of cut in most of the bedrock areas was less than 6 inches. During the closure process, there was a concern that a 1-foot cap (one of the pre-approved designs) could unacceptably reduce the cross-sectional area of the river; however, analysis showed that the potential impact did not meet the minimum threshold for concern. The decision was made to place 6 inches of backfill instead of a cap over most of the bedrock-obstructed inventory areas in CU-5. Much of this area was smooth bedrock without apparent crevices (GE video) and in a large majority of the bedrock areas core locations were abandoned and no grab samples were obtained. The remaining 6 inches of backfill that were to be placed over the bedrock were actually placed in a deep hole in CU-5 to raise the surface to the photic zone for future planting and to assist in habitat recovery as allowed by the standard. For the rest of the CUs the bedrock-obstructed inventory areas were less than one acre and the majority of those areas was capped.

The Phase I Residuals Standard did not anticipate conditions where bucket refusal would be encountered at a depth of six inches. Areas with 6 inches or less of material were not to be targeted for dredging.

5.4.8 CU-1 – An Example of Challenges at Areas Containing a Debris Field

CU-1 was the most challenging CU dredged during Phase 1, largely due to the debris field discovered during dredging. The presence of the suspected wood processing debris adversely impacted the SSAP coring effort and the delineation of DoC for dredging design, in addition, the debris was contaminated with PCBs. It is expected that conditions encountered in CU-1 will be the exception to the rule for Phase 2; however, this CU illustrates the need to employ a coring method that can penetrate debris to reach the uncontaminated material below and to fully remove debris fields encountered during dredging prior to attempting to collect post-dredging cores and close the CU. The first indication that CU-1 was exceptional was that 31 of the 33 SSAP cores were incomplete, the highest fraction of incomplete SSAP cores among Phase 1 CUs. A large number of adjacent incomplete cores should signal a concern that debris may be encountered and that the design cut line will only be an estimate of the true DoC, and preparations should be made accordingly. Examining CU-1 first, although it was unusual in comparison to the other CUs, also provides the opportunity to give detailed descriptions of the tools used examine all of the CUs.

The inadequacy of the design cut line in CU-1 can be readily shown. To clearly present information from SSAP cores and post-dredging cores and to compare the final dredging depth with the design cut line, cross-sections were generated at fourteen locations in CU-1. Figure II-5.4.8-1 shows the locations of the cross-sections. These cross-sections are approximately perpendicular to the river flow direction. Every core location in the CU is represented on one of the cross-sections. Figure II-5.4.8-2 presents a fence diagram of all the cross-sections. These cross-sections are also presented one-by-one in a series of plots (Figure II-5.4.8-3 plots a through n). The cross-sections show the pre-dredging bathymetry, design cut lines determined using SSAP coring data, sediment elevation after the final dredging pass, as well as total PCB concentrations in core samples. Three core sets, *i.e.*, SSAP cores, cores collected after the first dredging pass (first pass cores) and cores collected after the final dredging pass (final pass cores), are included in the cross-sections. For the purpose of clarity, cores collected after interim dredging passes are not included in the cross-sections.

Because only two of the 33 SSAP cores in CU-1 were complete (see Figure II-5.4.8-3g and 3k), the DoC was underestimated by about 6 feet on average and at almost all locations. The first dredging pass reached the design cut line with a tolerance of three inches and the associated post-dredging cores only penetrated to a maximum depth of twenty-five inches. Most of these first pass cores were incomplete and did not penetrate the entire thickness of the contaminated sediment inventory, nor were these cores analyzed to depth. While the presence of debris caused core refusal, the RAM QAPP (GE, 2009b) specified that the cores only be advanced to a depth of four feet. The post-dredging cores would not have reached the true DoC in CU-1 even if they had been fully advanced. Only six of 43 first pass cores were complete.

After five dredging passes with a cumulative dredging depth up to 13 feet deeper than the design cut line and an average additional depth of about 6 feet, a large amount of PCB inventory was still left in-place and the navigation season was coming to an end. Among the 32 final pass post-dredging cores, 24 were incomplete. At least one incomplete core was observed in every cross-section below the final dredging depth, showing the final dredging pass did not reach uncontaminated sediment in most areas of CU-1. Since coring was not able to fully penetrate the inventory due to the presence of debris, test pits were excavated at five locations (SRC-04, SRC-13, SRC-23, SRC-27 and SRC-37) to find the DoC. Four test pits encountered clay at the bottom and one encountered rock. Cores were taken at the four test pit locations and the average elevation of the DoC was found to be 99.7 ft NAVD88, or (with rounding) an elevation of 100 feet.

Figure II-5.4.8-4 shows the Tri+ PCB concentrations in the final pass cores. The average concentration of Tri+ PCBs in the final pass cores is 37.9 mg/kg, with a maximum value of

133.3 mg/kg. The concentration of Tri+ PCBs is greater than 1 mg/kg in more than 80 percent of the samples.

As shown in Figure II-5.4.8-3, most cores collected after the final dredging pass as well as after the previous passes for CU-1 did not penetrate the full depth of inventory (the requirement of the Residuals Standard was for post-dredging cores to penetrate 4 feet, which was not enough in many places in CU-1) and did not show a vertical profile with PCB concentrations decreasing with deeper core segments.

The intended removal of PCBs from CU-1 was not fully achieved and CU-1 was capped with contaminated sediment inventory remaining in place because the navigation season came to an end, requiring the dredges to be demobilized. In summary, the CU-1 SSAP cores did not adequately characterize the DoC and the post-dredging cores were incapable of determining DoC after the initial dredging pass, although they did demonstrate the presence of missed inventory. The difficulties were in large part due to the SSAP cores not being able to penetrate the debris found in CU-1. Incomplete SSAP cores and post-dredging cores were also important to dredging performance in the other CUs.

6. RESIDUALS STANDARD MODIFICATIONS FOR PHASE 2

The Phase 1 effort had many successes; however, the information gathered during Phase 1 also provides a basis to improve and streamline the performance standards specific to Hudson River conditions. As described in the Engineering Performance Standards document (USEPA, 2004), it was anticipated that changes to each of the performance standards would be facilitated and guided by the observations, successes and problems that arose in Phase 1. This section provides a proposed list of revisions to the Residuals Standard and design and management of the dredging project, along with a brief description of the evidence supporting the need for the revision.

The objective of the Residuals Standard is to ensure removal of all PCB-contaminated sediment in exceedance of the ROD criterion. As currently written, the standard assumes that design dredging cut lines would be set such that all PCB-contaminated sediments in exceedance of the ROD criterion are removed on the initial dredging pass, leaving behind only uncontaminated sediments below the cut lines, and overlying that, a comparatively thin layer of dredging residuals. Hence, the action levels defined in the Residuals Standard are geared towards confirming removal of PCB inventory and characterizing residual sediment (*i.e.,* sediment spilled or dislodged but not captured during dredging operations) concentrations in the top 6 inches.

Because the DoC was not defined for many post-dredging cores and the standard does not require the re-characterization of the DoC in all post-dredging cores, inventory material present beneath compliant surface residuals may be left behind. This may result in areas with unaccounted inventory that is not dredged or capped. To account for this, the Residuals Standard should be revised to require the DoC to be confirmed via the post-dredging core sample analysis after every dredging pass. The DoC is presumed to be defined where two contiguous 6-inch segments with less than a 1.0 mg/kg concentration of Total PCBs have been obtained.

Due to the amount of missed inventory encountered and area capped during Phase 1, the proposed changes to the standard do not use the 99% UCL as a threshold for re-dredging. A CU average Tri+ PCB concentration greater than 1.5 mg/kg will require re-dredging of all the nodes that contribute to an elevated mean concentration. This change is recommended because, during Phase 1 dredging, once a node was selected for dredging the average of the CU was recalculated assuming that the concentration of the re-dredged node was non-detect. This resulted in a higher number of residual nodes being classified as compliant; however, in many cases following re-dredging, PCB inventory was identified in samples collected from nodes that were previously identified as compliant, which resulted in nodes that were identified as compliant in the previous pass to be non-compliant in a subsequent pass. This process also resulted in compliant nodes becoming non-compliant nodes and thus needing to be capped at the end of the CU closure process (refer to Section II-5.1.3).

A reevaluation of the statistical basis for concentration maxima, averages, and medians used in the Residuals Standard was conducted. The evaluation did not prompt the modification of any of the threshold criteria in the Residuals Standard. The basic assumptions underlying the framework of the Residuals Standard have been largely borne out by the observations of Phase 1. Specifically, residuals have poor spatial correlation and form a skewed distribution, which can be approximated as log-normal. For this reason, and as long as a well-characterized DoC and design cut lines are used to pursue removal of all PCB-contaminated sediments above 1 mg/kg Total PCBs, no revisions to the structure of the Residuals Standard (*i.e.,* the numerical criteria) are proposed.

It is EPA's understanding that the primary difficulties in meeting the Residuals Standard were due primarily to the inadequacy of the design in targeting the DoC. EPA has written elsewhere about problems in the basic measurement of DOC and flaws in the core extrapolation methods (Kern, 2005) as well as failure to adequately hedge against uncertainty in the deterministic model used to interpolate DoC at unsampled locations.

Given these circumstances, it is EPA's opinion that the Residuals Standard performed well at identifying post-dredging residuals contamination and unexpectedly also performed well at identifying un-dredged inventory of PCBs found below design elevations in 10 of 10 CUs. Based on these findings, EPA assumes that DoC will be targeted much more aggressively in Phase 2 and that Residuals Standard will be used to confirm that target concentrations have been achieved rather than as a means to essentially 're-design the removal project in the field.'

Under this assumption and based on the fact that the Residuals Standard indeed identified high residual concentrations it was designed to prevent, it is the EPA's belief that if the DoC is more accurately and aggressively targeted prior to implementation of the Residuals Standard the critical thresholds could remain unchanged and it may be appropriate to remove point by point comparisons associated with higher percentages of the residuals distribution. It is EPA's belief that this would streamline the decision-making cycle and improve the speed with which CUs can be closed out, reducing the potential for freshly disturbed sediments to contribute to downstream water column loads of PCBs.

Conversely, if the Phase 2 design proceeds without substantial revision of the methods and data used to identify DoC it is EPA's opinion that the Residuals Standard should be substantively revised. In effect, the Residuals Standard would need to be more stringent in accordance with its previously unanticipated application to confirming the DoC. In this circumstance, the EPA recommends that the decision rule be modified so that acceptance is achieved when the upper confidence limit for mean residuals concentrations is less than the 3 mg/kg threshold currently being compared directly with the sample arithmetic average. The purpose of this more rigorous modification to the standard would be to hedge against the substantial uncertainty that is now known to exist in the design elevations, even in the vicinity of apparently complete cores.

Further recommended changes to the standard are associated with the conditions under which sub-aqueous caps can be placed. Because the standard currently does not require identification of DoC with each round of post-dredging sampling, caps were placed over inventory sediments. It is proposed that the conditions under which caps can be constructed be restricted to include only sediments that are proven to be:

- isolated residuals - those where the average is greater than 1.5 mg/kg but less than or equal to 3 mg/kg with no node greater than 15 mg/kg, or

- recalcitrant residuals or inventory – those where the CU mean is greater than 1.5 mg/kg and/or the DoC greater than 6 inches after 4 dredging passes or more. In this case, GE can petition EPA to place a cap.

In addition, at least a 9-inch overcut (18 inches where uncomplete cores are the basis for determining DoC) will be required in the dredging design to address the uncertainty in the DoC.

Table II-6-1 provides a summary of the revised structure of the Residuals Performance Standard. Note that the revisions proposed in this table assume that the DoC has been re-characterized or further adjustments to DoC have been made and the CU has been dredged to that DoC. It is also recommended that the 20-acre average evaluation be removed from the Residuals Standard.

Before beginning the detailed list, it should be noted that EPA's goal in proposing these revisions is to address many of the important issues while also simplifying the compliance process for the Residuals Standard. EPA considers the extensive increase in remediation volume during Phase 1 and the high degree of variability in the DoC to be the major concerns requiring redress in the Residuals Standard for Phase 2. Both of these issues can be best addressed by adjustments to the core collection process and the addition of overcutting (a design change), which are described below. Note that the ROD anticipated a 6-inch overcut to the design cut lines, although this was not implemented in Phase 1 by GE. The recommendations presented below are based on observations that indicate that the premise of the ROD was correct.

1. For Phase 2, the current design cut lines can form the initial basis for a revised estimate of the final dredging volume. While the presence of incomplete cores was problematic in estimating the final CU volumes, ultimately all Phase 1 CU volumes increased by a minimum of 60 percent, even when the density of complete cores was nearly 100 percent. While some additional coring may be needed prior to or during Phase 2, an extensive pre-

dredge sampling to obtain additional cores is unlikely to greatly refine these estimates. Given that the design surface required an additional 6 inches of dredging in about 70 percent of the SSAP locations and an additional 12 inches at 55 percent of the SSAP locations, it is clear that the original design surface plus an overcut between 6 and 12 inches (*i.e.,* 9 inches) will accurately capture the true DoC about two-thirds of the time. Where the DoC in a CU is based on incomplete cores, the overcut should be increased to 18 inches. The addition of a more rigorous post-dredging core collection program, as described below, will serve to confirm the DoC and provide better targeting for any subsequent dredging passes. Thus, the existing design surface with the addition of an overcut and a more rigorous post-dredging coring program will provide a competent basis for Phase 2 dredging.

A careful evaluation of complete versus incomplete SSAP cores needs to be conducted and estimates of DoC revised in order to better design the Phase 2 program. This evaluation can be prepared as part of the Final Design Report for Phase 2. It may be necessary to re-evaluate the DoC in some areas with a low fraction of complete cores by an alternative sampling method, such as split spoons or Shelby tubes, that can penetrate the full thickness of contaminated sediment in areas where vibracoring met refusal (*e.g.,* areas containing wood debris). This coring does not need to be completed prior to the initiation of Phase 2, so long as sampling procedures and a robust method for interpolation of the data and incorporation of overcuts, to arrive at Phase 2 design cut lines, are in place. The recommendations in this paragraph are supported by the following observations and conclusions:

a. In all CUs, the mean design cut lines were shallower than the final dredging depth by a minimum of 0.7 ft. The greater the frequency of incomplete cores in the CU, the greater the difference between the design and final dredging elevations; but all design cut lines were underestimated. Because the DoC was underestimated, several CUs required more than three inventory dredging passes to be completed and inventory was left in place at several CUs (*e.g.,* CUs 1, 4, and 7).
b. When the SSAP cores for a specific CU were largely complete, the actual dredging volume yielded the smallest increase over the design volume. These increases were still substantive, indicating that there will be notable volume increases over the design volume even when the SSAP cores are largely complete within a given CU. This is exemplified by experiences in CUs 17 and 18, where both CUs had a proportion of complete SSAP cores (Level 1A) of 90 percent or higher. For both CUs, low average PCB concentrations were observed after the first pass. The actual volume removed in CUs 17 and 18 exceeded the adjusted design dredging volume by about 70 and 60 percent, respectively, which is generally less than at other (less-well characterized) CUs.
c. Actual dredging volumes exceeded design dredging volumes for every CU completed. The total volume removed was about 1.8 times the original design volume for the 10 CUs dredged and additional inventory was left in the river. With CU-1 removed from the

evaluation, the average volume removed was 1.6 times the design volume for the remaining 9 CUs.

d. The actual mass of Total PCBs removed exceeded the design estimate. The estimated mass of Total PCBs removed was 20,000 kg relative to the design mass of 13,000 kg, an increase by a factor of 1.5. Note that the removal mass estimated by EPA is roughly 3,700 kg greater than GE's estimate of removal mass.

e. The original design volume was adjusted to reflect shoreline setbacks and bathymetric changes that occurred between the Final Design and the start of Phase 1, to reflect the pre-dredge conditions most accurately. Using the adjusted pre-dredge volume as a basis, the actual volume removed was slightly more than twice the adjusted design. This basis would indicate that on average, the depth of removal was twice the original planned depth. For Total PCBs, the actual mass removed was 1.8 times greater than the adjusted basis of 11,400 kg.

2. The Residuals Standard requirement for post-dredging core collection and analysis should be modified. Because the distribution of contamination is spatially heterogeneous (vertically as well as laterally), the complete sediment column to a depth of 2 feet below the surface elevation or to uncontaminated material (whichever is shallower) should be analyzed for every post-dredging core immediately after collection. At minimum, every core should have 2 contiguous segments with Total PCB concentration less than 1.0 mg/kg to establish the DoC. This revision is not intended to change the numerical DoC threshold of 1 mg/kg Total PCB used in Phase 1 but rather to verify that the entire contaminated sediment thickness has been penetrated by the core. Also, the terms "residuals core" and "inventory core" should be abandoned in favor of "post-dredging" core. As implemented, the Residuals Standard's sampling requirements were not always prescriptive enough to reveal the true DoC/final dredging elevation required after the initial dredging pass and subsequent core collection. This was particularly true at locations where the DoC was poorly estimated by the SSAP cores. For this reason, inventory removal (*i.e.,* a removal thickness of 1 foot or more) was necessary on nearly every dredging pass during Phase 1, even when four or five passes were conducted. No dredging pass should be allowed to commence until all nodes in the CU or the portion of the CU being evaluated have a DoC established by core segment measurements or by visual verification of specific, uncontaminated geologic formations such as Lake Albany clays. Taken together, these requirements will simplify compliance with the Residuals Standard since the final DoC will be attained with fewer dredging passes. With fewer passes, CU closure can be completed in a more timely manner. The ROD objective of removal of all contaminated sediments above 1 mg/kg can be attained.

3. Dredging should be conducted to fully remove wood debris when it is encountered. Wood debris from historic wood processing activities was encountered throughout Phase 1 and was shown to be extensively contaminated with PCBs. When this material is encountered in Phase 2 areas, it should be removed without further coring or testing since it is difficult to sample but readily identified while dredging. This will serve to reduce the required number of dredging passes, reduce the need for capping, and significantly help to speed the remediation. The design depth of cut should be adjusted to include an overcut of 9 inches

when sediment inventory is targeted (and 18 inches where the DoC is based on incomplete cores). For residual sediment contamination of 6 inches or less, at least 3 inches of overcut should be added to the planned removal thickness. These overcuts are recommended in response to several important observations regarding the design cut lines, the success of dredging passes and the final dredging depth required. By adding an overcut allowance to each pass, the dredging operation will more rapidly attain the true DoC for the CU and reduce the number of dredging passes required to attain compliance with the standard. The supporting evidence for these recommended overcuts is is summarized below:

a. The final dredging depth was more than 6 inches deeper than the original design cut lines for nearly 70 percent of the SSAP locations. The final dredging depth was greater than 12 inches deeper than the original design cut lines for 55 percent of the SSAP locations. Thus, the actual DoC is consistently deeper than the design cut lines by 6 to 12 inches and supports the recommendation for at least a 9-inch overcut. The variability of DoC precludes a precise cut line design (or fine grading), as documented by the multiple passes and high residual sediment concentrations observed in Phase 1 and the evaluation of co-located SSAP core data. In order to obtain a compliant surface in a limited number of passes, the uncertainty and heterogeneity in DoC needs to be factored in by adding an overcut allowance that reflects the magnitude of this variability.

b. The overcut is unlikely to add substantially to the volume to be removed. The extensive evidence obtained in Phase 1 shows the design DoC underestimates the true DoC by 50 percent or more on a CU-based average. Since the average design DoC for most CUs is greater than 2 ft, the 9-inch overcut represents a 35 percent volume addition. Given that nearly 70 percent of Phase SSAP core locations required 6 inches of additional dredging and 55 percent required 12 inches of additional dredging, the selection of at least a 9-inch overcut should strike a fair balance between too much overcutting and more rapid completion of the CUs. This amount still does not account for the likely final CU removal volume, the equivalent of a 12-inch or more overcut on the average CU DoC. The ranges of additional dredging depth required vs. the design cut line elevation are discussed further in Section II-2.0.

4. When determining the limits of re-dredging between a compliant node and a non-compliant node, the location of the compliant node must serve as the boundary. Based on evaluation of Phase 1 residuals data, spatial correlation among the samples collected is weak to non-existent and therefore no basis for interpolation can be discerned. Also, sampling at 80-foot centers, as required for Phase 1, represents the absolute minimum acceptable sampling density; a wider spacing of core samples would not be acceptable. The basic assumptions underlying the framework of the Residuals Standard have been largely borne out by the observations of Phase 1. Specifically, residuals have poor spatial correlation and form a skewed distribution, which can be approximated as log-normal.

5. The Residuals Standard should be simplified with respect to its application; reducing time spent analyzing compliance and subsequent actions.

a. The Standard offered nine possible conditions after initial dredging, from which response decisions would be made. Of these, only 4 conditions were actually encountered in Phase 1. Thus, for Phase 2, the list of conditions should be reduced to 4 to reflect the lessons learned in Phase 1 and simplify the assessment of compliance with the standard. The proposed revision is presented in Table II-6-1. Implicit in these requirements will be accurate characterization of the entire DoC in all locations. In Phase 1, the occurrence of inventory removal on nearly every pass, regardless of CU or core completeness, is the direct result of the combination of actual DoC variability, lack of core completion and a DoC surface interpolation that did not recognize these uncertainties. As a result, only one or two true "residuals" dredging passes were made in Phase 1. Thus the Residuals Standard for Phase 2 should recognize these limitations of DoC assessment and its application should be simplified.

   The original Residuals Standard cases should be reduced into 4 main categories:

   - Standard Met or Almost Met
   - Residuals Present
   - Inventory Present
   - Recalcitrant Residuals or Inventory Present

   Of the original Residuals Standard cases given in Table 2-5 of the Engineering Performance Standard (USEPA, 2004), Case A remains the same. The combination of B and C into Case A1 recognizes the high frequency of occurrences of high post-dredge sediment concentrations. Original Cases D and H relate to the use of a 20-acre average which went unused and does not appear workable. A new Case B is added to address non-compliant conditions that have no evidence of PCB contamination at depth. Original Cases F and G are effectively combined into the 'Inventory Present' option, new Case C, since more rigorous DoC characterization will be required on every pass regardless of the surface concentration distribution, in recognition of the high DoC variability. The Phase 1 Case E will be modified to require at least one dredging pass targeting a DoC of no more than 6 inches before any node can be capped (*i.e.,* a "residuals" pass is always required before capping). Additionally, Case E (which becomes new Case B1), has a lower allowable threshold before capping can be implemented to reduce the undesirably high frequency of capping that occurred in Phase 1. The last option is new Case D, Recalcitrant Residuals or Inventory Present, which specifically identifies a response when 4 dredging passes have been completed. The supporting analysis for this recommendation is discussed in more detail in Chapter II Section 3.4.5.

b. Identification of non-compliant nodes should be simplified, using a target average value of 1.0 mg/kg Tri+PCB. To simplify the process, the average is applied using only the ranked, measured nodal values. A simple accumulating average should be used to identify the first node that causes the mean to exceed 1.0 mg/kg Tri+ PCB. This node and all higher valued nodes must be dredged on the next dredging pass.

This represents a significant simplification from the Phase 1 approach, which required a substitution-based average ranking scheme. The allowance for low anticipated values at redredged locations was not borne out by the post-dredging measurements. As implemented in Phase 1, locations that appeared to be compliant with the standard on one pass later caused the mean to exceed the Residuals Standard threshold after later passes, requiring redredging (or capping) in the previously compliant location. This problem is eliminated by this simplified process.

The new implementation will also target a concentration of 1.0 mg/kg Tri+PCB and only permit a mean of 1.49 after the last pass, thus identifying all nodes likely to cause an exceedance of the Residuals Standard threshold. Similarly, areas that are identified as compliant will meet the true threshold of 1 mg/kg, regardless of the outcome of subsequent redredging attempts; there should be no change of node status from compliant to non-compliant. The process of construction of re-dredging boundaries should be simplified and streamlined. For locations where a single non-compliant node is surrounded by compliant nodes, the non-compliant node should be dredged to the periphery defined by the compliant nodes. For locations where a compliant node is surrounded by non-compliant nodes, the area associated with the compliant node should be dredged to the average depth of the surrounding noncompliant nodes. No area should be excluded based on a single compliant node. Three compliant nodes should be required to define an area that does not require re-dredging. These steps will eliminate the more sophisticated algorithm developed for Phase 1 that was a source of much discussion and often resulted in unusual dredging geometries. Additionally, the Phase 1 boundary definition process was predicated on a good DoC definition as well as spatial correlation in the data. The weakness of both of these premises does not support a complicated redredging geometry and instead indicates the need for more conservative sediment removal, reflecting these uncertainties. The simpler geometries should reduce both redesign preparation time as well as field implementation time. The evaluation of non-compliant nodes is discussed in more detail in Chapter II-5.0.

c. As mentioned above for Case B1, capping without a formal petition to EPA should only be allowed where actual DoC has been reached, followed by a dredging pass to manage residuals, if required. This is determined on a node by node basis and not on a dredging pass basis (*i.e.,* each node selected for a cap must have had an inventory dredging pass as well as a pass targeting 6 inches or less). This requirement reflects the high DoC variability resulting in the lack of a true “residuals only” pass. In addition, the other requirements of Case B1 must be satisfied to allow capping in this instance.

6. Capping of CUs should not be permitted as a direct result of running out of time in a navigation season. Since several seasons of dredging are anticipated, work in the CU can continue in the following season as needed, as long as all subunits of a CU dredged within a season are closed at the end of that season. Since Phase 2 will require a better definition of DoC throughout the dredging process, extended dredging periods for individual CUs should be minimized, aiding in timely completion of each CU and avoiding the impetus to cap an area prematurely. Finally, as in Phase 1, capping will be permitted subject to EPA approval after 4 dredging passes for inventory and residuals or after 2 consecutive “residuals” passes, if less than 4 passes have been completed. In the latter case, all nodes dredged in the last two passes must have had a target DoC of 6 inches or less. However, it is likely that by robustly establishing DOC and assuring that it is met during initial dredging, most CUs should be completed in less than 4, and likely within 2 dredging passes. If there had been enough time for additional residual passes, it is likely that little sediment inventory would have been capped. These simplifications and revisions are a direct response to the construction of caps in 9 of 10 CUs. In particular, this is the result of several instances of capping where schedule and process and not dredging difficulty were the factors driving capping decisions. Schedule is not expected to be a driver in determining areas that need capping in Phase 2.
7. Thin dredging lifts (or fine grading) should not be permitted. Dredging by thin lifts to smooth the sediment surface and meet a small design tolerance after the bulk of the sediment has been removed should not be permitted due to the combined impacts on productivity schedule, resuspension and residuals. For the same reasons, thin lifts should not be used as means to remove bulk volume. In both instances, the high degree of uncertainty in the DoC surface as well as variability in sediment contaminant levels do not support the targeting of sediments for removal on less than a 6-inch basis. Additionally, the time consumed in such dredging is not justified since the probability of extensive redredging is high even when the CU contains a high number of complete cores. A minimum target thickness of 9 inches (6-in residual thickness plus 3-in overcut allowance) is recommended.
8. EPA and GE should work together to simplify data management and transfer. A streamlined data exchange process, such as internet data sharing, should provide additional time for EPA review while actually shortening the calendar time in the review process.

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Section 6

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CHAPTER III
EVALUATION OF THE PRODUCTIVITY STANDARD IMPLEMENTATION

CHAPTER III SUMMARY

The Engineering Performance Standard for Dredging Productivity (Productivity Standard; USEPA 2004, Volume 4) establishes a schedule for the dredging project and provides guidelines for monitoring its progress to ensure that it is completed within the time period identified in the Record of Decision (ROD). The Productivity Standard requires compliance with minimum cumulative volumes of sediment to be removed during each dredging season, which are shown in Table III-1-1 of this document. While the actual volume removed during Phase 1, exclusive of access and navigational dredging, was estimated at 273,600 CY by EPA and 282,900 CY by GE, only 10 of the 18 CUs targeted for dredging in Phase 1 were completed. The difference between the dredging project, as designed, and the Phase 1 implementation can be attributed to an underestimation of the actual depth of contamination (DoC) in each CU. During Phase 1, larger volumes than anticipated in the design were removed from each CU dredged. If CU-1 is excluded from the calculation as an anomaly, the average volume actually dredged at each CU was approximately 1.6 times that anticipated during the design.

A new estimate of the total volume remaining to be dredged was needed to support a valid analysis of the prospects for meeting the Productivity Standard in Phase 2 under the current design. Since the Phase 1 results indicated a consistent underestimate of DoC in each CU, two estimates of the potential additional volume that may require dredging during Phase 2 were prepared. Both approaches assumed that the large overrun in quantity in CU-1 was an anomaly. The first estimate applied a factor of 1.6 (incorporating the median increase from design volume encountered during Phase 1) and the second estimate is based on increasing the design estimate of the DoC by approximately 1.13 feet, the average increase in the DOC as found during Phase 1.

The design dredging volume for both Phases 1 and 2 was 1,795,000 CY, which is about 68 percent of the total ROD-estimated dredging volume of 2,650,000 CY that was utilized in the Productivity Standard. The re-estimates of dredging volume, based on experience gained during Phase 1, yield estimated dredging volumes of 2,600,800 to 2,872,000 CY, which are still very close to the original dredging volume estimated in the ROD. As a result, the original Productivity Standard volume of 2,650,000 CY for both Phase 1 and Phase 2 has been utilized in evaluating GE's ability to complete the project over the five years of Phase 2. The revised required volumes and target volumes for Phase 2 are provided in Table III-3-3. Further refinement of design dredging volumes should be conducted successively as Phase 2 of the project is planned and implemented.

The General Electric Company's (GE's) Weekly Productivity Summary Reports indicate that many hours of potential dredging time were lost during Phase 1 due to:

- Circumstances that can be controlled or mitigated:
  - A shortage of empty hopper scows.
  - The practice of allowing free water to drain from the dredged bucket before placing sediment into the mini-hopper scows due to their limited capacity.
  - The consumption of a significant amount of time while the dredge operators conducted fine grading operations at the end of each dredging pass to meet tight vertical tolerances specified, often times only to find that the inventory was significantly deeper and that additional passes would be required to remove it.
  - Time spent in preparing bathymetric maps, sampling, designing new cut lines and obtaining EPA's approval of new cut lines to remove previously unidentified contaminated sediment inventory following completion of the dredging to the depths shown in the initial design.
- Circumstances that cannot be controlled:
  - High river flows that prevented dredging.
  - Storms/inclement weather.
  - The presence of bedrock in close proximity to the dredging cut line.
- Circumstances that may or may not be controllable:
  - Suspension of dredging due to action required by the Resuspension Standard.
  - Dredge buckets that do not completely close due to the presence of woody debris.

About 40 percent of the time available to dredge during Phase 1 was lost due to the causes listed above. A summary of the number of potential dredging hours lost due to causes beyond the control of the dredge operators is presented in Table III-3-4.

Dredging was completed in 48.3 acres of the approximately 90 acres targeted for Phase 1. Backfill was placed over approximately 31 acres and engineered caps were constructed over approximately 17.3 acres. Backfill and capping materials were placed to within the tolerances specified in the design without undue difficulty. Some problems encountered during backfill work were due to backfill gradations that were not appropriate to maintaining stable slopes in near-shore environments, and the gradation and utility of Type 1 backfill should be reevaluated for Phase 2. Due to deeper than anticipated DoC, the volume of backfill required to achieve submerged aquatic vegetation reconstruction design elevations increased significantly in some CUs. Deeper than anticipated backfill also complicated the anchoring of biologs called for at some shoreline stabilization locations, and alternative approaches for constructing wave breaks and installing biologs and geotextiles at riverine fringing wetlands should be explored for Phase 2.

The shipment and disposal of dewatered sediment encountered several unexpected problems during Phase 1, including problems with rail car unloading, rail car cleaning and return shipment, and a disposal cell slope failure that occurred at the disposal facility. It is likely that these concerns can be addressed prior to Phase 2, such that rail cars can be loaded and dispatched from Fort Edward, and unloaded at the disposal facility, at a rate sufficient to handle the estimated sediment volumes to be dredged each year during Phase 2.

While some problems were encountered and lessons learned during Phase 1, there is every indication that if Phase 2 activities are planned appropriately (*e.g.*, an adequate number of empty scows is made available), the project can achieve the Phase 2 productivity targets. The maximum amount dredged during any one month period in Phase 1 was estimated by GE at 78,000 CY; however, had empty scows been available and had the dredgers not expended additional time attempting to meet the tight vertical tolerances specified for the dredge cut between multiple dredging passes, it is likely that the Phase 1 dredging production could have exceeded the monthly amount required to meet Phase 2 targets.

The following additional recommendations are provided for Phase 2:

- Steps should be taken to better define DoC for Phase 2 to minimize the number of dredge passes needed to remove missed inventory. If sediment cores do not clearly define the 1 mg/kg PCB horizon, some over dredging should be required.
- Post-dredging core samples should be collected <u>prior</u> to, rather than after, conducting fine grading of the river bed to correct areas where the cut line was found to be slightly higher than the design cut line. During Phase 1 there were many cases where post-fine grading sampling indicated significant additional inventory below the design cutline which effectively meant the fine grading step was unnecessary or at least highly inefficient. Sampling prior to fine grading would address this inefficiency and minimize the need for fine grading.
- Dredging necessary to gain access to a CU should be conducted immediately prior to dredging that CU so that the dredge platforms and scows can operate efficiently.
- Heavy duty environmental buckets capable of shearing through wood debris and closing more quickly and frequently should be obtained, if available.

- Draining free water from closed dredge buckets increased cycle time and should be prohibited during Phase 2. Other methods should be considered to control excess water in mini-scows.
- Scows should be loaded to their maximum capacity, consistent with vessel stability, during Phase 2. The average volume of solids carried in a large hopper scow during Phase 1 was 421 CY; the maximum volume of solids recorded in a scow was 929 CY.
- Changes to scow unloading systems and coarse materials separation systems are needed to ensure that Phase 2 production rates are met. Options that might be considered include the addition of a second unloading station and the use of shaker screens rather than the trommel screen currently in use for initial separation of coarse sediments. Large balls of clay should be handled separately from other materials.
- The Productivity Standard should be modified to permit EPA to extend the timeframe for Phase 2 if necessary to accommodate conditions beyond the control of EPA and GE, such as extreme river flows, force majeure, or the discovery of significant additional inventory to be removed.
- The Productivity Standard should be modified so that sediment volumes removed during residual dredging and when dredging missed inventory are counted toward meeting required and target volumes listed in the Standard. GE requested, and EPA approved, this change for Phase 1 and it should be carried forward into Phase 2.

1 OVERVIEW OF THE PRODUCTIVITY STANDARD FOR PHASE 1

1.1 General

The Productivity Standard establishes a schedule for the dredging project and provides guidelines for monitoring its progress to ensure that it is completed within the time period identified in the ROD. The project schedule described in the ROD has a six-year duration and consists of one initial dredging season, designated Phase 1, and five additional dredging seasons collectively designated as Phase 2. Phase 1 consists of initial dredging at a reduced scale with extensive monitoring to evaluate compliance with the Engineering Performance Standards. Phase 2 consists of dredging at full production to remove the remainder of the contaminated sediments targeted for removal.

The term “Dredging,” as used in the Productivity Standard, includes removal of the contaminated sediment, dewatering and disposing of the dredged sediments, backfilling dredged areas with one foot of clean fill as appropriate, stabilization of shoreline areas disturbed by the work, and habitat replacement and reconstruction. During design of the project it was decided that planting of submerged aquatic vegetation should be done in the spring season rather than at the completion of dredging in the fall. Accordingly, EPA and GE agreed that this work would be done in the spring following each year’s dredging work.

Statement of the Productivity Standard for Phase 1

The Productivity Standard requires compliance with minimum cumulative volumes of sediment for each dredging season and targets larger volumes for the first five dredging seasons as shown in Table III-1-1. In particular, for Phase 1 the minimum volume required to be dredged was set at 200,000 cubic yards (CY) while the target volume was set at 265,000 CY. In addition, the Productivity Standard requires that the Phase 2 production rate be met for a one month period during Phase 1 in order to verify that the dredging operation, including the dredging equipment and the sediment processing and transportation systems, can meet the production rates anticipated to be necessary during Phase 2.

1.2 Initial Volumes and Production Rate Estimates

The volume of contaminated sediment referred to in the Productivity Standard is the volume as measured in situ in the riverbed. The total volume to be dredged in Phases 1 and 2 was estimated in the ROD (ROD Table 8-18) at approximately 2,650,000 CY. This estimate was based on sediment sampling data available through the end of 2000 (October 2000 Hudson River Dataset, Release 5) and was adopted for use in the Productivity Standard. This estimated volume included allowances for overcut and side slopes, material dredged for access purposes, and material dredged for habitat replacement and reconstruction purposes.

While it was recognized that the 2.65 million CY volume used in the Productivity Standard was only an estimate, it was clear that some minimum volume of sediment would have to be dredged each year if the project was to be completed within the six-year timeframe stated in the ROD. It also appeared desirable, given the uncertainties associated with dredging production rates actually achievable in the field and the potential for delays in the work caused by high river flows, equipment breakdowns, and other uncontrollable factors, that the project should be designed to provide for some cushion within the six-year schedule. Accordingly, the Productivity Standard included a "target" production rate as needed to complete the project approximately midway through the final year of dredging in addition to the "required" minimum production rate necessary to complete the project by the end of the full six-year period.

Utilizing the 2.65 million CY estimate as the total volume to be dredged in Phases 1 and 2, the required volume to be dredged in Phase 1 was set at 200,000 CY. The required volume to be dredged in Phase 2 was then calculated as 2,650,000 CY – 200,000 CY = 2,450,000 CY, or 490,000 CY annually. For design purposes, the target production rate for Phase 1 was set at 10 percent of the ROD volume, or 265,000 CY. The target production rate for Phase 2 was then established based on an expectation that dredging would be completed by the middle of the last year of Phase 2, allowing the second half of the last year to serve as a 'catch-up' period at the end of the program. The target production rate for years two through five of dredging (years one through four of Phase 2) were calculated as 530,000 CY per season (2,650,000-265,000)/4.5 = 530,000) and the target production rate for year six of dredging (year five of Phase 2) was calculated as the remaining 265,000 CY. These volumes are summarized in Table III-1-1.

1.3 Inventory vs. Residuals Dredging

The ROD and the Engineering Performance Standard for Dredging Residuals (Residuals Standard; USEPA 2004, Volume 3) require that dredging be carried out to achieve an average PCB concentration in areas dredged of 1 mg/kg of Tri+ PCB or less before backfilling. The Residuals Standard as applied in Phase 1 defines two categories of dredging: "inventory" dredging and "residuals" dredging. Inventory dredging refers to the bulk removal of contaminated sediment to the elevation in the river bed at which the Tri+ PCB concentration is estimated to be 1 mg/kg. Residual dredging generally refers to cleanup dredging to remove a shallow layer of sediment, usually 6 inches deep or less, to achieve the average of 1 mg/kg Tri^{+} PCB cleanup criteria in those areas where this target cleanup level has not been met during the initial inventory dredging efforts.

When the Residual Standard was written, it was assumed that pre-design sampling would provide the data needed to accurately define the depth of contamination in most areas, that dredging to that depth would remove all or most of the inventory of contaminated sediment, and that residuals dredging would only be required to remove any thin layers of contaminated sediment left behind due to fall-back from the dredge, slope failures at the edges of dredge cuts, failure of the dredge operator to overlap cuts, the difficulty of removing all sediment laying directly over an uneven bedrock surface, and similar problems. As originally written, the Residuals Standard limited residual dredging to a maximum of two passes over an area under the assumption that, if the remaining contaminated sediment was indeed confined to the uppermost 6 inches of the river bottom and this material could not be removed in two additional dredging attempts, any further attempts would likely be unproductive. In this case, the contaminated sediment would be covered with an engineered cap and left in place. However, the Residual Standard did not set a limit on the number of attempts that would be required to remove inventory sediments under the assumption that, if sampling conducted after the sediment is removed to the initial design cut elevations finds that PCB concentrations are higher than anticipated or that a layer of contaminated sediment in excess of 6 inches thick is still present, the dredge cut lines were not properly defined in the design. In this case, new dredge cut drawings would have to be submitted to EPA for approval and additional inventory dredging conducted to reach the 1 mg/kg Tri+ PCB concentration horizon.

The requirements for inventory dredging and residuals dredging were written into the Residuals Standard with two purposes in mind. First, by not limiting the number of attempts required to remove inventory sediments, an incentive was created to accurately determine the depth of contaminated sediment that must be removed to reach the horizon at which Tri+ PCB levels fell below 1 mg/kg and to set the design cut lines to that elevation or below. An accurate determination of the depth of contamination during the design of the dredging program would minimize the need to re-sample and re-dredge areas where the original cut lines were drawn too shallow. Secondly, removing a thin layer of sediment, which may frequently be relatively fluid in nature, can be a slow and painstaking process and will not result in the removal of a large mass of sediment or PCB. Limiting the number of residual dredging attempts required to remove residuals minimizes the impact on overall dredging production during the project.

As noted in the footnote to Table III-1-1, the required and target dredging volumes shown in the table did not include dredging to remove residuals sediment or missed inventory sediments. Subsequently, GE requested and received EPA's concurrence that "missed inventory" should be included in the volume measurement. In addition, GE requested that the required number of dredging attempts to remove inventory sediments be limited to two and received EPA's approval with the expectation that the inventory would be removed in two attempts. (USEPA/GE, 2005). A recommendation is included, herein, for changing the Productivity Standard to include both "missed inventory" and residual dredging in the volumes that are counted toward meeting the Standard in Phase 2.

1.4 Other Requirements of Productivity Standard

Other requirements established by the Productivity Standard include the following:

- That for a time period of at least one month during Phase 1, the minimum production rate shall be the rate required to meet the Phase 2 Performance Standard in order to verify the capabilities of the dredging operations, including the dredging equipment and the sediment processing and transportation systems. At the time that the Productivity Standard was written, this rate was estimated at 70,000 CY/month based on a seven-month dredging season and a required minimum production rate of 490,000 CY per year.

- That stabilization of shorelines and backfilling of areas dredged during any year be completed by the end of that calendar year (i.e., prior to the following spring high flow period in the river).

- That all material dredged during any year be processed and shipped off-site for disposal by the end of that calendar year.

1.5 Provisions for Revising Volume and Production Rate Estimates

In recognition of the fact that the ROD-specified 2.65 million CY estimate of the contaminated sediment volume was likely to change once additional sediment sampling was conducted, the Productivity Standard provided for revising the volumes to be dredged as follows:

- A change of 10 percent or less in the overall volume will be addressed by revising the required volume for the final year of Phase 2.

- If the volume of sediment to be dredged changes by more than 10% as a result of the sampling program and final design considerations, the Phase 2 required and target volumes will be adjusted using the same approach that was used to develop the volumes presented in the Productivity Standard.

1.6 Revision of Volume and Production Rate Estimates as a Result of Sampling

In 2002, GE began a major sediment sampling and analysis program to better define the volume of sediment required to be dredged. Over 11,700 sediment core samples were collected and over 50,000 individual sample analyses were completed. The results of this work were published in three separate reports:

- A Phase 1 Target Area Identification Report (GE, 2004) which identified areas in the portions of the Thompson Island Pool where the concentration of Tri+ PCB in the surface sediments exceeded 10 mg/kg and/or the mass per unit area of Tri+ PCB exceeded 3 grams per square meter ($g/m^{2)}$, the target levels defined in the ROD for River Section 1.

- A Phase 1 Dredge Area Delineation Report (GE, 2005) which outlined the approximate horizontal limits and depth of contaminated sediment to be dredged during Phase 1.

- A Phase 2 Dredge Area Delineation Report (GE, 2007) which outlined the approximate horizontal limits and depth of contaminated sediment to be dredged during Phase 2. These areas include additional areas in the Thompson Island Pool where the concentration of Tri+ PCB in the surface sediments exceeded 10 mg/kg and/or the mass per unit area exceeded 3 g/m^2, and those areas in River Section 2 (between the Thompson Island Dam and Northumberland Dam) and River Section 3 (between Northumberland Dam and Federal Dam in Troy) where surface sediment Tri+ PCB concentrations exceeded 30 mg/kg and/or the mass per unit area exceeded 10 g/m^2, the target levels defined in the ROD for these two river sections.

As a result of this sampling program, GE estimated that the volume of sediment to be dredged during Phases 1 and 2 of the project would be approximately 1.8 million CY. However, this volume was calculated on the basis of removing just that depth of sediment needed to reach the point where the total PCB concentration dropped to 1 mg/kg and did not include any allowances for over-excavation or for additional dredging passes to remove missed inventory. It was understood by EPA and GE that this estimate was likely to change somewhat as design drawings were developed to define dredge cut lines for each season's dredging effort and sampling was conducted following initial dredging.

Upon completion of the design for Phase 1, GE prepared a new estimate of the volume of contaminated sediment anticipated to be dredged during each phase of the project. The revised estimate was published in a Phase 1 Performance Standards Compliance Plan (PSCP; GE, 2009b) prepared by GE pursuant to the requirements of the Consent Decree (USEPA/GE

2005). While noting that this plan addressed Phase 1 only, it described GE's estimate of minimum and target removal volumes for Phases 1 and 2 based on the total estimated volume of approximately 1.8 million CY. This estimate is presented in Table III-1-2.

The PSCP also noted that the dredging season would be 5.5 months long, and that inventory removal was scheduled to be completed in 120 dredging days based on dredging 6 days per week for 20 weeks. The remainder of the season was assumed to be needed to conduct post dredge sampling and residuals dredging, backfilling and construction of any necessary engineered caps. Inasmuch as the 5.5 month dredging season assumed in the PSCP was considerably shorter than the seven month season assumed when the Productivity Standard was written, a targeted one-month test volume of 89,000 CY was proposed rather than the 70,000 CY contained in the Productivity Standard.

2.1 General

The project design was based on the use of mechanical dredges, scow transport of dredged sediments and mechanical dewatering. Design Contracts awarded by GE for Phase 1 included the following:

- Contract 1 - Facility Site Work Construction. Contractor: D.A. Collins, Inc.
- Contract 2 - Rail Yard Construction. Contractor: Railworks, Inc.
- Contract 3A - Processing Facility Construction. Contractor: Sevenson Environmental Services, Inc.
- Contract 3B - Processing Facility Operation. Contractor: Shaw Environmental Inc.
- Contract 4 - Dredging Operations. Contractor: Jay Cashman, Inc.
- Contract 5 - Habitat Construction. Contractor: ENSR, an AECOM company. (Habitat construction will begin in Spring 2010.)
- Contract 6 - Rail Yard Operations. Contractor: MHF Logistical Solutions, Inc.
- In addition to the above, GE entered into a contract with Waste Control Specialists (WCS) for disposal of the dredged sediment at that company's landfill in Texas.

2.2 Dredging Design

2.2.1 Target Areas and Dredging Cut Lines

Design drawings showing the locations and depths of sediment to be removed and specifications governing the dredging process were prepared by GE on the basis of the sediment sampling program results and modeling of contaminated sediment depths (see GE 2005; GE 2007). In accordance with the Residuals Standard, the area targeted for dredging in Phase 1, approximately 90 acres overall, was divided into 18 “certification units” (CUs) of approximately 5 acres each. These CUs were developed to facilitate approval of the dredging and backfilling work in increments as the project progressed. A map identifying these CUs is shown in Figure III-2-1.

Dredging was generally scheduled to proceed from upstream to downstream. CUs 1 through 16 are all located between river miles 194.5 and 193.1. CU-17 and CU-18 are located along the easterly side of the river near Griffin Island, approximately three miles downstream from CU-16 and downstream from areas scheduled to be dredged during Phase 2 of the project. CU- 17 and CU-18 contain fine grained sediments and were selected for a Special Study aimed at comparing losses of resuspended sediments to downstream areas when dredging in open water versus those attainable when dredging within enclosures constructed using either steel sheet piling or conventional silt curtains.

The dredging cut lines were drawn to remove just that depth of sediment needed to reach the elevation at which the total PCB contamination dropped to 1 mg/kg as estimated by GE. No over-cut was included in the design drawings or specifications to account for a potential under-estimate of the depth of contamination or for inaccuracies in determining the actual elevation of the dredge bucket. The ROD was based on the premise that once an area was targeted for dredging, the targeted removal was 0 mg/kg Total PCB inventory remaining.

Section 13801, Inventory Dredging, Part 3, paragraph 3.01C, of GE’s specifications for Contract 4, Dredging Operations, defined the criteria under which the contractor’s dredging work would be accepted.

> “The final elevation of the dredge cut for inventory dredging shall be at or lower than the inventory removal average elevations shown on the Dredge Prism XYZ File based on average post-dredge elevations over a 1-acre area using high-resolution bathymetric survey data. This determination will be made by comparing the two surfaces within this one-acre footprint such that the volume of sediment remaining above the Dredge Prism XYZ file for that same one-acre area is less than the volume of sediment removed below the Dredge

Prism XYZ File for that same one-acre area, both volume calculations will be based on 10-foot by 10-foot grid average sounding datasets. In addition, any 10-foot by 10-foot grid within a CU (as defined by a grid overlain on the CU) having an average elevation 3 inches or more higher than the elevation shown on the Dredge Prism XYZ file shall require additional inventory dredging."

2.2.2 Shoreline Dredging Issues

The horizontal limit of dredging along shorelines was defined as the elevation 119-foot contour line (North American Vertical Datum of 1988; NAVD 88), which corresponds to the river water level at a flow rate of approximately 5000 cfs. Because of concerns about the potential for destabilizing the river bank if deep, vertical cuts were made immediately at the shoreline, GE proposed that the depth of cut at the 119-foot contour line be limited to a maximum of 2 feet. If the depth of contamination at the shoreline was greater than 2 feet, a 2-foot cut with vertical side slope would be made at the 119-foot contour line and the cut line would then proceed downward into the river at a slope of 3H to 1V until the full depth of contamination was reached. This approach is shown in Figure III-2-2. Where the depth of contamination at the shoreline was less than 2 feet, the cut line would be designed to just reach the base of the contaminated layer. Since limiting the dredging depth to 2 feet at the shoreline in areas where contamination extended below that level would leave a small wedge of contaminated sediment behind, it was determined that all shoreline sediments with a 50 mg/kg or higher total PCB concentration should be removed but sediments with a total PCB concentration less than 50 mg/kg could be left in place and covered with an engineered cap.

Other shoreline erosion and stabilization issues addressed during the design included procedures to be followed where rip-rap is present and methods to be employed to protect large trees growing at the 119-foot contour line. A significant length of shoreline in the Phase 1 dredging areas is protected by rip-rap constructed by the New York State Canal Corporation (NYSCC). Generally, this rip-rap extends from some point well below the low water level to the approximate 100-year flood elevation at approximately elevation 124 feet NAVD 88. Much of this rip-rap was constructed at least 50 years ago and brush and small trees are growing through it. There was concern by GE that removing the portion of the rip-rap below the 119-foot contour elevation could undermine the stone above that elevation and cause significant bank failures, while removing and replacing all of the rip-rap in areas slated for dredging could have a significant impact on productivity and damage existing habitat. Therefore, along shorelines where rip-rap is present, the design called for dredging to begin at a point approximately 5 feet from the face of the rip-rap and proceed downward at a slope of 2H to 1V until the full depth of the contaminated layer is reached as shown in Figure III-2-3.

In areas where large trees located immediately at the river's edge were deemed critical to protecting the shoreline from erosion, dredging began at a point approximately 3 feet from the tree root ball and proceeded downward at a slope of 1H to 1V to the bottom of the contaminated layer as shown in Figure III-2-4.

In open water areas, the design called for transitions between deep dredge cuts and shallower cuts and at the boundaries between dredged areas and adjacent areas where no dredging took place to be made at a slope of 3H to 1V or flatter if required to achieve stable side slopes. This was done to minimize the potential for causing erosion of the river bed at these locations and requires the removal of some sediment outside the boundary between dredged areas and areas not targeted for dredging.

2.2.3 Backfill and Capping

The ROD called for a one-foot thick layer of clean backfill to be placed in most areas dredged to cover any remaining contamination. The design called for the use of three backfill types. Type 1 backfill consists of a mixture of sand and gravel for use in portions of the river where velocities are generally less than 1.5 feet per second (fps). Type 2 backfill consists of a coarser mixture of sand and gravel for use in areas where the velocity is greater than 1.5 fps. These two backfill types were designed for use in unconsolidated river bottom areas, including the near-shore and submerged aquatic vegetation habitat reconstruction areas. Type 3 backfill consists of a mixture of sand, gravel and topsoil and was designed specifically for riverine fringing wetland habitat reconstruction.

The design also required that additional backfill be supplied to restore shoreline areas between elevation 119 and 117.5 feet to their pre-dredging contours. Furthermore, in some potential submerged aquatic vegetation habitat reconstruction areas where dredging would result in water depths greater than 8 feet, the design calls for additional backfill (beyond the one-foot thick layer generically called for in the ROD) be placed to raise the river bed elevation into the photic zone. GE raised concerns about the amount of additional backfill that might be called for and requested that it be limited to a maximum of 22,748 CY, which is equal to 15 percent of the amount of backfill needed to cover the entire Phase 1 dredging area of approximately 90 acres to a depth of 1 foot. This additional backfill is referred to herein as "additional 15 percent backfill." Based upon information available at the time relative to the depth of dredge cuts, EPA thought this was a reasonable request and agreed to the limitation, but has maintained that this limitation might need to be modified based upon the findings of Phase 1. Preliminary locations for installing this additional 15 percent backfill were identified during design and a procedure was established to allocate the material once dredging had been completed and actual, post-dredging river bottom elevations were known.

For certain situations where dredging does not achieve the cleanup goal, the Residuals Standard permits installation of an engineered cap over residual contaminated sediment. Cap type designs reflect varying residual Tri+ PCB concentrations and 10-yr flood water velocities. Caps were not proposed in the Phase 1 design as a primary remedy element but rather as a contingency for use in accordance with the backfill/capping decision matrix provided in the Residuals Standard.

The Phase 1 design documents specify five different subaqueous caps for use under different circumstances. Type A caps were designed for physical isolation only and were designated for use in areas where Tri+ PCB concentrations in the residual sediments were less than or equal to 6 mg/kg. Two varieties of Type A caps were designed, one for use in areas where flow velocities are less than or equal to 1.5 fps, and one for areas where velocities exceed 1.5 fps. Type B caps were designed to achieve both physical and chemical isolation and contained a specified minimum level of organic carbon in their components. Three varieties of Type B caps were designed for use under different flow velocity conditions. Table III-2-1 provides a summary of the different type caps.

2.2.4 Shoreline Stabilization and Reconstruction

Shoreline stabilization is necessary in most areas where dredging extends to the water's edge. The design called for various shoreline stabilization measures at the 119-foot contour to counter the effects of erosion from wave action. The default stabilization measure is passive and involves the placement of near-shore backfill. Active measures include the installation of biologs in areas where the shore is subject to mild erosion forces and Type P stone in areas where wave action from wind or vessels is significant.

The design dictated that any shoreline/stream bank habitat areas disturbed by dredging operations above elevation 119 feet be reconstructed with stone, topsoil, seed mixes, and/or live-stakes. Shoreline reconstruction and restoration details are shown on plan sheets B0021 through B0023 in the Contract 4, Dredging Operations, design drawings.

2.2.5 Resuspension Control Measures

In addition to the sheet piling and silt curtains installed near Griffin Island for the Special Study of methods to reduce resuspension losses, the design called for several other protection measures. These include:

- The use of oil booms in areas where oil sheens were noticed on the river.

- The construction of a rock dike at the upstream end of the navigation channel along the east side of Rogers Island where some of the highest PCB concentrations were found in the sediment. Sluice gates were installed in the rock dike to control the flow through this channel in an effort to reduce scouring of the river bottom as the dredges moved over the area.

- The installation of a silt curtain near the southerly end of the channel along the east side of Rogers Island.

- The use of silt curtains or sheet piling on a contingency basis if resuspension of sediment into the water column was found to be a problem in other areas.

2.2.6 Tree Trimming and Debris Removal

Prior to beginning dredging in any area, overhanging trees at the water's edge were trimmed back or cut and removed to provide access for the dredges and underwater debris identified during the design was removed. The wood (limbs and tree trunks less than 8 inches in diameter) and brush from tree trimming were chipped on the barge. The chips were blown into a container and off-loaded from the chipping barge for disposal at the Washington County landfill. Limbs and trunks larger than 8 inches in diameter were loaded onto deck barges, transported to the wharf at the dewatering site, and stockpiled for subsequent disposal. Debris, including sunken logs, cables, and miscellaneous large objects, were removed from the river bed, transported to the dewatering site and, ultimately, loaded onto rail cars for shipment to the disposal site.

2.3 Floating Plant

2.3.1 Tree Trimming and Debris Removal Equipment

The tree trimming fleet consisted of three independent barges constructed from FlexiFloat sections that were pinned together. One barge held a manlift used by the certified arborist to access the trees and tree tops that were to be trimmed or removed and storage racks for tree sections larger than 8 inches in diameter. The second barge held the fleet office, CONEX supply boxes, power generators and a crane used to remove limbs and trunks after being cut. The third barge held the chipping machine and chip receiving box.

The tree trimming operation was assisted by a number of small skiffs that managed harbor booms surrounding the larger barges and collected tree parts that fell into the river during removal (see Figure III-2-5).

The debris removal barge consisted of two barges constructed from FlexiFloat sections and pinned together. The main barge held a CAT 320 excavator fitted with a claw type extractor. This barge also held a barge control office, CONEX supply boxes, sanitary facilities and power generators. The second barge section was a mini-hopper barge into which debris was placed (see Figure III-2-6).

2.3.2 Dredges

The dredges used during Phase 1 of the project consisted of fixed arm, hydraulic excavators mounted on deck barges and equipped with hydraulically operated, enclosed buckets that produce a relatively level cut. A total of 12 dredges were available for most of the season. Five of these were Caterpillar 385 excavators equipped with 5-CY buckets, one was a Caterpillar 345 excavator equipped with a 2-CY bucket, and six were Caterpillar 320 excavators equipped with 1-CY buckets.

The enclosed buckets were manufactured by The Grab Specialists, BV of the Netherlands. The 5-CY bucket had a footprint of 14.7 feet by 7.1 feet (104.4 sq. ft.) when fully opened and, assuming no expansion or swelling of the sediment as it was excavated, required a 15.6-inch depth of cut to fill. The 1-CY bucket had a footprint of 9.3 feet by 4.3 feet (40 sq. ft.) and was filled when the depth of cut was about 8 inches. The 2 CY bucket had a footprint of 5.05 feet by 10.69 feet and was filled when the depth of cut was about 12 inches.

The dredges were equipped with a Real-Time Kinematic (RTK) Differential Global Positioning System (GPS) to position the dredge bucket within tolerances of plus-or-minus 2 inches vertically and plus-or-minus 3 inches horizontally, as produced by HyPack, Inc. Hypack's Dredgepack® software was programmed with dredge prism input files on a gridded interval of 1 foot by 1 foot to control the position of the bucket for each bite of sediment. This system also provides a record of each successful dredge bucket bite and records the real-time movement and position of the excavator and bucket for review at any time. Dredging bites that are unsuccessful due to a partial closing of the bucket from debris or other malfunction are not logged as a successful bite and are reacquired to obtain the removal of material initially acquired from the original location. Once successful, the bite is logged into the system. Additional detail on the data review and analysis of Dredgepack® logs generated during the Phase 1 activities is provided in Section III 3.4.1.

2.3.3 Scows

Dredged material was placed in scows and moved by tug boat to the dewatering site on the west side of the Champlain Canal north of Lock 7. A number of different size scows were used for the project. A total of 18 large hopper scows with double walls were available for use in areas where the depth of water was adequate to accommodate their draft. These scows varied in size from approximately 190 feet to 200 feet long and 30 to 35 feet wide with allowable drafts of 11 feet (although a maximum draft of 8 feet was established by the dredging contractor for stability purposes). When empty they had a draft of approximately 1.5 feet. The scows were reportedly designed for bulk cargo such as coal or ore but are approximately 20 years old and nearing the end of their useful lives. Some scows developed cracks in their walls and floors and had to be taken out of service temporarily for repair. Ullage tables for the large hopper scows are included in Appendix III-A.

In addition to the large hopper scows, nine small "mini-hopper" scows measuring approximately 26 feet by 18.5 feet and one scow measuring approximately 52 feet by 18.5 feet were available during most of the season for use in shallow areas of the river. The mini-hopper scows were constructed on-site using Flexifloats and steel plates; all had 2 foot high walls. Each of the 9 mini-hopper scows has a capacity of approximately 35 CY if filled to the top of the walls, while the single larger scow has a capacity of about twice that amount. However, to prevent the overflow of free water in the dredged sediment, they could only be partially filled. Typically, about 25 CY of sediment could be placed in each smaller scow and 40 CY in the larger scow before the material was transferred to a large hopper scow moored in deeper water.

2.3.4 Tug Boats

Seventeen tug boats were available to support the movement of scows and other barges. Some of these tug boats were equipped with 350-hp engines while others had 650-hp engines. All had a draft of approximately 3 feet. Typically, two tugs were required to move a large hopper scow from the dredging operations to the unloading wharf, although three tugs were occasionally used when river flows and current velocities were high. In addition to the 17 tug boats, the dredging contractor had four utility tugs with outboard motors. Three of these small tugs were used to move mini-hopper scows, and one was used in conjunction with a maintenance barge.

2.3.5 Backfilling and Capping Equipment

Backfill and capping materials were stockpiled on the west shore of the river opposite Rogers Island and loaded onto barges using a conveyor system. The backfill and capping materials were placed using the same excavators used for dredging but with different buckets mounted on the excavators. Eight deck barges were available to transport backfill and capping materials from the stockpile area to the point of use in the River. These barges were of varying sizes up to approximately 35 feet wide by 196 feet long. Backfill and capping materials were transferred to mini-hopper scows for use in shallow water areas. The bucket positioning systems on the excavators were used to control the location and rate of swing of the excavator arm and the opening of the bucket jaws as the backfill or capping material was installed.

2.3.6 Work Support Marina and Support Vessels

To support the water borne operation, a work support marina was constructed on the west side of the river opposite Rogers Island. This marina provided dock space for survey and oversight boats and was used as an embarkation point for the dredging contractor’s staff. Water taxis operated around the clock to carry personnel to and from the dredges. The total number of vessels operating on the river at any one time approached 90 when all survey boats, dredges, tugs, water taxis and ancillary craft were operating.

2.4 Dewatering Facility Design

The dewatering facility was designed to handle an average of 3,500 CY and a peak of 5,100 CY of dredged sediments per day. A brief description of the facility is presented below.

2.4.1 Unloading and Work Wharf

A 1500-foot long unloading and work wharf was constructed along the west side of the Champlain Canal between Locks 7 and 8. The unloading portion of the wharf was equipped with a winch system to move scows along the face of the dock as they are unloaded, but this system failed during the first few days of use. Thereafter, a tug boat was used to reposition scows for unloading.

Loaded scows arriving at the wharf were moored adjacent to a pump-out station where free water was removed. Initially, a single pump-out station was employed and the water was pumped to a mixing tank on shore. In the middle of July, a second pump-out station was added to the system because unloading was found to be proceeding more slowly than anticipated during the design. The water from this second system was discharged to a storm water retention basin on the site. Each dewatering pump was rated at approximately 2260 gallons per minute (gpm) at 160 feet of head. Because the pumps require a head of approximately 1 foot of water over their inlets to prevent air from entering their impellers, they were not capable of removing all of the free water from a scow.

Once free water had been removed, the scow was repositioned adjacent to a Komatsu 1250 excavator with a 5-CY, hydraulically actuated bucket used to remove the sediment. When fully open, the bucket had a footprint of 11 feet by 7 feet and required a 21 inch depth of cut to achieve its full, 5-CY capacity. This excavator had a rated capacity of 333 CY per hour based on a 50 minute hour and a 45 second cycle time, provided that the scow contained a sufficient depth of sediment to fill the bucket during each cycle. However, as the depth of material remaining in the scow fell below 21 inches, the bucket could not be filled with each bite and the production rate dropped off. In order to maintain a reasonable rate of production as the depth of sediment remaining in the scow fell below this level, a remote-controlled Bobcat excavator was lowered into the scow to push the sediment into a pile.

If the scow contained coarse material, it frequently could be unloaded directly into off-road dump trucks for transport to the coarse material staging stockpile. Fine grained sediments and wet sediments were unloaded into a trommel screen.

2.4.2 Coarse Materials Separation System

Sediment in the scows that could not be unloaded directly into dump trucks was placed in a trommel screen for initial separation into coarse and fine grained material. The trommel screen was designed to remove material greater than 5/8 inches in diameter and had a rated capacity of 5.4 CY per minute, or 6840 CY per 20 hour day. Sediment was fed into the trommel through a grizzly screen with 12 inch openings to remove large debris. The grizzly screen was mounted above a dump box similar to that found on a dump truck. In operation, sediment removed from a scow by the Komatsu excavator was dropped onto the grizzly screen and fell through the screen into the dump box. The grizzly screen was then tilted to a nearly upright position with hydraulic pistons and any large debris on its surface fell to a stockpile at its base. Next, with the grizzly screen in its tilted (upright) position, the dump box was raised to discharge the sediment into the trommel. Material larger than 5/8 inches in diameter was removed by the trommel screen and discharged onto a radial stacking conveyor which stockpiled it for transport by truck to the coarse material staging area. Material finer than 5/8 inches in diameter passed through the trommel screen into a hopper below the screen. A picture of the trommel screen is shown in Figure III-2-7.

Originally, the material passing through the trommel screen was pumped to a 25,000 gallon sediment slurry tank equipped with a mixer and from this tank to hydrocyclones for further processing. However, during start-up testing, the shaker screens beneath the hydrocyclones experienced premature failure as a result of the large volume of gravel in the sediments and it was decided that a further size reduction step should be added to the system. Accordingly, a shaker screen with a ¼ inch mesh was installed immediately downstream from the trommel screen to reduce the size and volume of sediment fed to the hydrocyclones. As ultimately configured, the material passing through the trommel was pumped to a shaker screen mounted above a new mixing tank and the material passing through this screen was pumped from this new tank to the original sediment slurry tank and then on to the hydrocyclones.

The hydrocyclones were designed to separate silt and clay from coarser material. Two hydrocyclone systems were furnished. Each consists of a hydrocyclone cluster and a dewatering screen mounted above a sump. Each system is designed to produce an underflow with 70 percent dry solids, by weight, at an influent flow rate of 2250 gpm. The underflow from the hydrocyclones is dewatered on fine mesh shaker screens and stockpiled for transport to the coarse material staging area. The over flow is pumped to a sediment slurry thickening tank prior to being dewatered in filter presses. A picture of the hydrocyclone system is shown in Figure III-2-8.

2.4.3 Fine Sediment Dewatering System

The overflow from the hydrocyclones consists of a slurry of water, silt, clay and very fine sand. This material was thickened and then dewatered in filter presses. The sediment slurry thickener is a gravity thickener consisting of an elevated, 80-foot diameter steel tank with a 12-foot minimum side-water depth and a hopper shaped bottom. The thickener was designed to receive sediment slurry with 1.6 to 12.1 percent dry solids and thicken this slurry to at least 15 percent dry solids. Polymers were added to the slurry to assist in the thickening process and condition the mixture for dewatering. The thickener tank is shown in Figure III-2-9.

Twelve plate and frame filter presses were installed to dewater the thickened fine sediments. Each press has its own feed pump. The presses were designed for a total flow of 1563 gpm with a solids concentration of 15 percent and a mass of 10,314 wet tons of solids per day. Each filter press has a capacity of 600 cubic feet (22.2 CY) per cycle and is designed to produce a filter cake with a minimum of 55 percent solids. If all 12 presses were operating with a cycle time of 3 hours, they could produce up to 2130 CY of filter cake per day. The presses were located in a 240-foot long by 172-foot wide building. Filter cake dropped into roll-off containers located under the presses and was transferred by tilt-bed truck to the fine material staging area.

2.4.4 Dewatered Sediment Storage

Storage for dewatered sediments is provided by open-air coarse material staging areas and an enclosed, fine materials (filter cake) staging area. The coarse materials staging area originally consisted of three, 310 feet long by 120 feet wide, open-air concrete bunkers. However, when regulatory problems halted the transportation of dewatered sediment to the disposal site, this staging area became filled to overflowing and an additional coarse materials staging area was constructed at the north end of the wharf.

The filter cake staging area consists of two, 400 foot long by 100 foot wide, stressed-membrane buildings. Pictures of the coarse material storage pile and the filter cake storage building are shown in Figures III-2-10 and III-2-11, respectively.

2.4.5 Water Treatment System

Storm water, water from decanting scows, filtrate from filter presses and decontamination water were treated in a water treatment plant and discharged to the Champlain Canal. The treatment system is preceded by two equalization tanks. One tank is dedicated to storm water while the other is dedicated to process water. The water treatment plant has a total installed capacity of 1500 gpm [2.16 million gallons per day (mgd)] and consists of three trains rated at 500 gpm (0.72 mgd) each. Each train consists of a rapid mix tank, flocculation chamber, inclined plate clarifier, mixed media pressure filter, two 20,000-pound granular activated carbon pressure filters, and two bag filter systems. A backwash water holding tank is located outside the building. The plant is designed to meet a 0.065 ug/L maximum discharge limit for PCBs established for the facility.

2.5 Rail Car Loading, Transportation and Disposal

Dewatered sediment from the coarse and fine materials storage areas were loaded into gondolas fitted with plastic sacks and shipped by rail to the WCS landfill located west of Andrews, Texas, near the Texas-New Mexico border. Dedicated unit trains of 81 gondolas containing from 102 to 105 tons of dewatered sediment each (8260 to 8505 tons per train) were used. The gondolas were loaded using front end loaders and each rail car was weighed on a weigh-in-motion scale as the train was assembled. The rail cars were unloaded by backhoe at the disposal site, broom cleaned, and returned to Fort Edward empty. Once the empty railcars returned to Fort Edward, they were pressured washed, lined with a plastic liner and refilled with dewatered sediment. Sufficient gondolas were available to provide up to 5-unit trains at any time.

3 DREDGING PRODUCTION

3.1 Scheduled Production

As noted in Section III 1, the volume of contaminated sediment targeted for dredging in Phase 1 was established as 265,000 CY of in situ material. This was revised to 245,100 CY due to the late start of the project in Spring 2009. The target removal goal for the one month productivity test (operating at Phase 2 production rates) was 89,000 CY. Dredging, backfilling and shoreline restoration work was scheduled for the period between when the locks on the Champlain Canal opened during the first week of May through October 15th. The specifications for Contract 4, Dredging Operations, stated that dredging was to occur from midnight Sunday to midnight Saturday, unless otherwise approved.

Dredging during the first few weeks of the project was purposely scheduled at a low production rate to test sediment resuspension rates in the river and permit a gradual ramp-up of work at the dewatering site. The scheduled production included in Remedial Action Work Plan #3 was as shown in Table III-3-1.

The Contract 4 Specifications also stipulated that a maximum of 5,100 CY of sediment could be delivered to the dewatering site daily.

On April 17, 2009, Jay Cashman, Inc., the dredging contractor, began tree trimming along the shoreline. This work did not require vessel passage through any locks and, therefore, began prior to the opening of the canal. Construction of the rock dike across the east channel at Rogers Island began on April 27, and dredging of approximately 600 CY of material from the Champlain Canal channel north of Lock 7 to increase its depth for navigation purposes began on May 6, 2009. Debris removal and dredging of contaminated sediment began on May 15, 2009 and ended for the season on October 27, 2009. Backfilling, capping and shoreline reconstruction continued until early December when work on the River was stopped for the winter.

3.2 Actual Volume Dredged

A comparison of bathymetric maps made at the start of the 2009 dredging season with those made upon completion of dredging in each CU was used to estimate the volume of material dredged during Phase 1. EPA estimates that a total of 273,600 CY of contaminated sediment was removed, exclusive of navigational and access dredging, which slightly exceeds the targeted volume of 265,000 CY. GE estimates that 282,900 CY were removed, or about 3.3 percent more than EPA's estimate. The difference between these estimates is still being investigated but is likely related to the fact that the 2009 pre-dredging bathymetric survey did not provide complete coverage of the river bottom in shallow areas immediately adjacent to shore. EPA used 2005 bathymetry to approximate the river bed elevations in these areas.

Although both EPA and GE's estimates of the actual volume dredged exceed the 265,000 CY targeted for dredging, only 10 of the 18 CUs identified for dredging in Phase 1 were actually completed. Table III-3-2 lists the CUs, their areas, the volumes to be dredged as listed in the design documents, EPA's estimate of the actual amounts dredged, and the percentage increase in the design amount. The volumes shown in the table do not include approximately 1200 CY removed from the Champlain Canal north of Lock 7, which was dredged to increase the depth in this channel for navigational purposes, or approximately 2200 CY of sediment dredged to provide access to some CUs.

As noted in Table III-3-2, significantly more sediment was removed from the ten CUs that were dredged than was originally anticipated. The greatest overrun in the estimated quantity occurred in CU-1 where the actual volume dredged amounted to 3.76 times the amount anticipated during design.

As discussed in the evaluation of the Residuals Standard (Section II 2.4), the estimates of the depth of contamination in the river bed used for the design of Phase 1 were consistently too low, at least for those CUs where dredging was completed. The estimated removal volumes shown in the design for CUs 1 through 8 plus CUs 17 and 18 amounted to 150,300 CY. EPA's estimate of the actual volume removed from these CUs amounted to 268,500 CY, or about 1.79 times the volume shown on the design drawings.

It is clear from the experience gained during Phase 1 that the method used to collect sediment core samples for design purposes was not appropriate for the field conditions actually encountered. Shortly after dredging began, it became apparent that the sediment contained a substantial amount of slab wood and other debris. The vibracore sampling device did not penetrate (met refusal) in the slab wood and other debris in the sediment and many of the cores collected were labeled incomplete. Procedures developed by GE to treat the incomplete cores, such as doubling core lengths to arrive at an estimate of the depth of contamination, proved to be ineffective in many instances and resulted in setting the design cut lines above the actual depth of contamination.

A significant portion of the overrun in design volume resulted from dredging in CU-1. CU-1, which encompasses the Fort Edward Yacht Basin, is located at the upstream end of the east channel at Rogers Island and is a natural settling basin for sediments washing downstream from above the Old Fort Edward Dam site. The NYSCC tries to maintain a water depth of at least 12 feet, measured at low water, for navigation throughout its system and conducts maintenance dredging to a depth of about 14 feet to provide for refill. CU-1 was dredged to a depth of approximately 14 feet in 1976, the last year that the NYSCC dredged PCB-contaminated areas of the Canal. By 2005, when GE had bathymetric drawings prepared for dredging design purposes, from 10 to 12 feet of new sediment had washed into parts of this area and the available navigation depth at low water had decreased to only 3 to 4 feet. Nevertheless, GE's design called for the removal of only about 2.5 feet of sediment in most of this CU-1 on the basis of core sampling results.

After completing what was anticipated to be the inventory sediment dredging in CU-1 to the grades shown in the design and sampling for residual PCB concentrations, GE directed the dredging contractor to conduct a residuals dredging pass over the area. In accordance with the design documents, approximately 6 inches of sediment were removed during this pass. When a second round of samples was collected and analyzed, PCB concentrations at the sediment surface were still above the 1 mg/kg Tri+ PCB concentration and deeper sections of the sediment cores were analyzed. The analytical results showed that the contamination extended to a much greater depth and that inventory sediments were still present. New cut lines were provided to the contractor and a second inventory dredging pass was made at depth.

The results of sediment cores collected after the second inventory dredging pass in CU-1 showed that PCB concentrations had still not decreased. An analysis of deeper sections of the new sample cores indicated that elevated PCB concentrations and woody debris extended further into the river bed, but the total depth of contamination could not be confidently determined. Accordingly, EPA agreed that GE would dredge all areas in the navigation channel to elevation 104.9 feet above mean sea level (MSL) before the next round of core samples was collected. Cores collected after this third inventory dredging attempt showed the continued presence of PCB and woody debris, and a fourth inventory dredging pass, to elevation 103.3 feet above MSL, was conducted to provide 12 feet of water depth in the navigation channel after capping. This dredging pass was completed October 24, 2009. Sediment cores collected and analyzed following this dredging pass indicated that the contamination went deeper still, but it was decided that it was too late in the season to attempt additional dredging. Therefore, the construction of an engineered cap was approved for much of this area.

Ultimately, an estimated 48,900 CY of contaminated sediment was removed from CU -1 during four inventory passes and one residual pass, or approximately 3.76 times the amount shown in the original design drawings. The overrun would have been even greater if dredging had not been halted to provide time for backfilling and capping before the closure of the Canal. Four test pits excavated with the dredge bucket on the last day of dredging encountered woody debris mixed with the sediments to depths of from 1 to 3 feet below the final cut line. The presence of this material, which is typical of the sediment that washed down steam following the removal of the Old Fort Edward dam, indicates that contaminated sediment, potentially amounting to an additional 10,000 CY, remained in this CU when dredging ended.

Sedimentation in the navigation channel has not been as severe downstream from CU-1. If the volume dredged in CU-1 is excluded from the calculation of the percentage overrun in the design volume, the average overrun in the remaining nine CUs is approximately 1.6 times the design estimate. This is still a significant increase in volume and calls into question the accuracy of GE's estimate of the total volume to be dredged in Phases 1 and 2 of the project.

3.3 New Estimate of Volume Remaining to be Dredged

A new estimate of the total volume remaining to be dredged is needed if a valid analysis is to be made of GE's ability to meet the Productivity Standard under the current design. Unfortunately, there are insufficient data available, at present, to make a rigorous analysis. Nevertheless, two approaches have been developed to arrive at a working estimate for use in this report. In the first approach, GE's estimated total volume of 1,795,000 CY for Phases 1 and 2 (see Section III 1, Table III-1-2.) has simply been increased by a factor of 1.6, the average increase in the design volume experienced during Phase 1 if CU-1 is excluded from the calculation. This produces a total volume estimate of 2,872,000 CY, which is approximately 8 percent more than the ROD-specified 2,650,000 CY estimate assumed for Phases 1 and 2 when developing the Productivity Standard.

The second approach is based on applying a simple increase in the depth of contamination to GE's estimates based on the experience gained to date. Under this approach, the increase in volume actually dredged over that estimated in the design has been converted to an increase in the depth of contamination by simply dividing the net increase in volume by the area of the CUs dredged to date. If CU-1 is excluded from the calculation, the net increase in volume dredged during Phase 1 was 82,100 CY over an area of 44.86 acres, or an additional 1.13 feet of dredging depth over the area. Another way of saying this is that a volume of 82,100 CY is equivalent to about 1.13 feet of sediment over 44.86 acres. If the area remaining to be dredged during the entire project is approximately 442 acres and an additional 1.13 feet of sediment has to be dredged from this area, the increase in volume will be approximately 805,800 CY. Adding this volume to GE's estimate of 1,795,000 CY yields a total volume estimate of 2,600,800 CY which is about 2 percent less than the ROD estimate utilized when developing the Productivity Standard.

The two different approaches used to estimate the total volume of sediment to be dredged during Phases 1 and 2 of the project are reasonably close, and both are close to the ROD-specified 2,650,000 CY used for the development of the Productivity Standard. Therefore, for the purposes of evaluating GE's ability to complete the project in five more years of dredging, without substantially revising the current design of the dredging and dewatering systems, the ROD-specified total volume of 2,650,000 CY has been assumed. Under this assumption, and taking note of the fact that an estimated 273,600 CY has been dredged in Phase 1, the volume remaining to be dredged in Phase 2 is approximately 2,376,500 CY. This is about 8,600 CY less than the 2,385,000 CY originally estimated for Phase 2 in the Productivity Standard.

The required and target volumes to be dredged during Phase 2 of the project, as assumed in the development of the Productivity Standard, are discussed in Section III 1 of this report. Inasmuch as a greater volume of sediment was dredged in Phase 1 than originally called for in the Productivity Standard, the required and target volumes for Phase 2 can be lowered slightly as shown in Table III-3-3.

3.4 Dredging and Sediment Processing Rates

3.4.1 Dredge Production Rates

In accordance with the Productivity Standard, GE prepared Weekly Productivity Summary Reports throughout the Phase 1 dredging project. A report, dated November 4, 2009, covers the project from May 6, 2009 to October 31, 2009 and is included in Appendix III-B. This report provides summary information on the estimated volume of sediment dredged each week, the CUs where dredging took place, the number of active dredges, the number of hours that dredges were available to work, the number of scows off-loaded at the dewatering site, the estimated average volume of sediment per scow, the average length of time required to off-load a scow, an estimate of the tonnage of sediment processed, and an estimate of the amount of water treated at the water treatment plant and discharged to the Canal. The report also contains information relative to delays in dredging that occurred during that period.

The Weekly Productivity Summary Report dated November 4, 2009, indicates that a total of 288,257 CY of sediment was dredged including material removed for navigational and access purposes. This volume was subsequently revised to 286,354 CY and included 3451 CY of navigational and access dredging. (As noted above, GE's estimate of contaminated sediment removed from the CUs, which excludes navigational and access dredging, is 282,900 CY and is slightly higher than EPA's estimate.) Nevertheless, GE's estimate is judged to be sufficiently accurate for use in evaluating dredging and sediment processing rates.

A review of the estimated gross volume dredged during each week, as reported in the Weekly Productivity Report, indicates that the maximum volume dredged in any one month period was approximately 77,000 CY. This was less than the 89,000 CY target established by GE for a one month test of the system, which was established by GE under the assumption of a 5.5 month dredging season during Phase 2. During Phase 1, dredging of contaminated sediments occurred on a 6-day per week schedule from May 15, 2009 to October 27, 2009, a 165 calendar day or approximately 5.5 month long period, and EPA agrees that 5.5 months is representative of an average dredging season given typical weather conditions and flow rates on the Upper Hudson River.

Assuming that the dredging season extends from May 1 to October 15 in an average year, that dredging occurs 6 days per week and that the dredging contractor does not work on Independence Day or Labor Day, a total of 141 days would be available for actual dredging. Based on the new estimate of the required Phase 2 dredging volume of 475,300 CY of in-situ sediment per season, the average required production rate would have to be approximately 3370 CY per day. To meet the target volume of 528,100 CY, the dredging rate would have to average 3745 CY per day. On a monthly basis, the required and target volumes would be 86,420 CY and 96,020 CY respectively.

A data compilation report (GE, 2009a) was prepared for GE near the end of the dredging season. Table 2.7-2 in that report provides information on the number of dredges working each day and each day's effective working time for these dredges. Effective working time, as defined in this table, is the time during the dredging operation when dredged material is being removed and does not include time spent on debris removal, tree trimming, loading/unloading mini-scows at transfer stations, or time lost when moving the dredge platform, changing shifts, refueling and similar operations. The effective working time during July, August and September, when up to 11 dredges were working in the River, was typically between 35 and 45 percent.

An analysis was made of the data recorded by the DredgePack software used on the dredges to estimate daily dredge production rates for the various size dredges, dredge bucket cycle times and the approximate volume of material removed by each bite of the bucket. A similar analysis was conducted for each CU dredged and for each separate dredge pass in a CU. The term "dredge pass," as used herein, means the effort needed to dredge a CU to the design cut line. It does not mean a single pass over a given point as part of a multi-pass attempt to dredge to a design elevation. The results of this analysis are shown graphically in Figures III-3-1a-j, III-3-2a-j, and III-3-3a-j.

CU-1 has been chosen as an example to illustrate the results of the DredgePack analysis. Figure III-3-1a shows the daily volume dredged in CU-1 and is based on GE's bucket analysis tables which record bucket counts per day and daily dredge volumes. As shown in this Figure, dredging began in this CU on June 4, 2009 and continued on a 6-day-per-week basis until the original design cut line for this CU was reached around July 14th. The dredging contractor did not work on the July 4th weekend and the graph shows no production around this date. For most of this period, a 5 CY dredge was employed in this CU although a 1 CY dredge was brought in at the end of the period to "fine grade" the area to meet the 3 inch plus or minus tolerance around the design cut line specified by GE in the dredging contract documents. Dredging production rates varied from over 800 CY per day to slightly less than 100 CY per day until the design cut line was met.

Over a six day period beginning around July 15, a bathymetric map was prepared to demonstrate that the design cut lines had been met, sediment samples were collected, and the uppermost 6 inches of the sample cores were analyzed. Based on the analytical results, GE elected to perform a residual dredging pass over the entire CU and remove an approximate six inch layer of sediment. This dredging pass (DP-2) began on July 22 and ended on August 18. A 5 CY dredge was employed for this work and the production rates varied from less than 50 CY per day to about 200 CY per day. Work was suspended between August 7 and August 11 due to high resuspension rates.

As the residual dredge pass neared completion, another round of sediment cores were collected and analyzed. The uppermost 6 inches of these sample cores contained higher levels of PCBs than anticipated and the remaining segments of the cores were analyzed. Based on the analytical results, it was determined that the original design cut lines did not reach the full depth of contamination and that a substantial amount of contaminated sediment inventory remained. Accordingly, new dredge cut lines were designed and given to the dredging contractor and a third dredging pass was begun on August 22.

Upon completion of the third dredge pass in CU-1 on September 19, a third round of core samples was collected and analyzed. The results showed that a significant depth of inventory sediments still existed in much of the CU and new cut lines were again designed and given to the contractor. Between September 26 and September 28, the contractor conducted access dredging in the navigation channel just downstream from CU-1 to allow more heavily laden scows to exit the CU. On September 30, the fourth dredging pass began in this CU and continued until October 15. During portions of this fourth attempt to reach the bottom of the contaminated sediment layer, the contractor used two 5 CY dredges and dredge production increased to as high as 1500 CY per day.

Ultimately, four inventory and one residual dredging passes were attempted in CU-1, but the bottom of the contaminated layer was not reached in all areas. Due to the onset of cold weather and the need to backfill and cap the river bottom in this CU, dredging was stopped on October 27.

The information presented in Figure III-3-1a illustrates some of the problems related to the inability to accurately define the DoC during the pre-design and subsequent sediment sampling programs. Productive dredging time was lost at the end of each dredging pass as the contractor attempted to achieve the close tolerances specified for the cut lines and much time was spent conducting new bathymetric surveys, collecting and analyzing core samples, and designing and obtaining EPA approval of new cut lines on four separate occasions in a single CU. In addition, the data show that, as might be expected, dredging production rates are generally much lower when attempting to remove a thin residual layer than dredging a thick inventory layer.

An analysis of median daily bucket cycle times during CU-1 dredging is shown in Figure III-3-2a. As shown in this Figure, median daily bucket cycle times varied from about 1 minute to over 4 minutes per cycle. The longer times are generally associated with the fine grading work at the end of a dredge pass and during the residual dredging pass, DP-1.The fastest cycle times were generally achieved during the initial phases of inventory dredging passes where a thick layer of sediment was being removed.

Figure III-3-3a presents the results of an analysis of dredge bucket filling efficiency during the dredging of CU-1 and is based on the daily bucket count for each dredge, the volume removed by that dredge each day, and the nominal volume of the dredge bucket used. For example, if a 5 CY dredge removed 500 CY of sediment in a day using 250 bites, or cycles, of the bucket, the average volume removed per bucket bite would be 2 CY and the bucket filling efficiency would be 40 percent. As shown in the figure, the 5 CY bucket was generally filled to less than 50 percent of its nominal capacity during the first dredge pass in CU-1 and fell to less than 20 percent during fine grading at the end of this dredge pass.

The fact that the average efficiency was only about 50 percent during the initial weeks of the first dredge pass in CU-1 is surprising inasmuch as the design cut called for dredging a sediment layer that averaged over 2.5 feet thick. The 5 CU bucket used in this CU would be filled to capacity at a cut depth of 15.6 inches. Normally, the dredge operator attempted to dredge to the dredge cut line elevation at each set of the dredge, and it may be that he reached a depth of 2.5 feet in two bucket bites of, say, one foot each and then made two additional bites to remove the last six inches of sediment. This would account for an average of 4 bites to achieve the 2.5 foot cut depth, or 7.5 inches per bite, and result in an average bucket filling efficiency of just under 50 percent.

During dredge pass 2, when the 5 CY dredge was used to remove a thin residual layer, the average bucket contained less than 20 percent of its nominal capacity, or about 1 CY per cycle. During the last week of this residual pass, the bucket filling efficiency averaged less than 5 percent. Based on the 5 CY bucket dimensions, a 20 percent bucket filling efficiency implies that the depth of cut was approximately 3 inches while a 5 percent filling efficiency implies a cut of less than 1 inch. When combined with median bucket cycle times well in excess of one minute, dredge production during the residual dredging pass was very low.

It should be noted that the analysis of bucket cycle times and bucket filling efficiencies was complicated by the fact that the DredgePack software did not record a bite if the bucket jaws were open more than about 2 inches as the bucket was lifted from the river bottom. Debris in the sediment frequently prevented the jaws from closing and these bucket cycles were probably not recorded. If more bucket cycles actually occurred than were recorded, the bucket cycle times discussed above would be shorter. However, the bucket filling efficiency would be lower.

3.4.2 Impediments to Meeting Dredge Production Rate Target

GE's Weekly Productivity Summary Report, dated November 4, 2009, shows that the total time that all dredges working on the project were available to dredge amounted to 18,125 hours over the entire season. It should be emphasized that this represents the total number of hours available to dredge, not the number of hours that dredging actually took place. Many hours of potential dredging time were lost due to a shortage of empty scows, high river flow rates, shut-downs due to high PCB resuspension rates, the presence of bedrock encountered above the design cut elevation, and other reasons. Nevertheless, based on GE's estimate of 286,359 CY dredged and the 18,125 hours of available dredging time, the dredge fleet averaged a dredging rate of only 15.8 CY per available dredge-hour.

A summary of the number of potential dredging hours lost due to causes beyond the control of the dredge operators, taken from the Weekly Productivity Summary Report, is presented in Table III-3-4 and in Figure III-3-4. These hours were compiled by GE from dredge captains' logs and other sources and show the amount of time that dredges did not work for various reasons. As shown in this table and figure, an estimated 4753 hours out of the 18,125 hours available for dredging were lost due to a shortage of empty hopper scows, 1090 hours due to high flows, 382 hours due to lightning storms, fog or other inclement weather conditions, and 1022 hours due to concerns about high concentrations of PCB in the water column. The estimated total dredge production time lost due to the causes listed above amounted to 7247 hours, or about 40 percent of the time that dredges were available to work. The table also lists 779 hours of time lost as dredge operators attempted to remove a thin layer of sediment overlying an uneven, clay surface. However, since these hours were actually spent in dredging, albeit at a slow rate of production, they have not been included in a summation of "lost" time.

An estimate of the actual time spent in active dredging, 10,878 hours, has been calculated by subtracting the 7247 lost time hours from the total number of hours available for dredging. Based on this number and GE's estimate of the total volume dredged, the dredge production rate has been calculated at 26 CY per dredge per hour.

GE estimates that the maximum production rate achieved during Phase 1 was approximately 78,000 CY over a 30 day plus 16 hour time period between July 5th and August 4th. A review of the information contained in the Weekly Productivity Summary report indicates that a maximum dredge production rate occurred during the 34 day period between July 5th and August 8th, 2009 and amounted to approximately 86,900 CY. Prorating this rate to a one month period yields an estimate of approximately 77,000 CY. The report also notes that a shortage of empty scows resulted in 1400 hours of lost dredge production during the first 27 days of this period. Had empty scows been available, and had the actual average production rate of 26 CY per hour per dredge been achieved during this time period, an additional 36,400 CY of sediment could have been dredged. This would have increased the 30 day production rate to over 113,000 CY, which is more than enough to meet the target production rate for Phase 2.

Other factors that affected dredge production rates include the presence of wood debris in the sediments that prevented the dredge buckets from closing completely, the practice of allowing free water to drain from the dredge bucket before placing the sediment into the mini-hopper scows due to their limited capacity, and the fact that bedrock was encountered above the design cut elevation in some CUs. In addition, a significant amount of time was lost as the dredge operators conducted fine grading operations at the end of each dredging pass to meet the tight vertical tolerances specified for the dredge cuts, only to find that an additional pass over most of the area was required to remove missed inventory sediments. Finally, the lack of empty barges had a negative effect on the morale of the dredge crews. Dredge captains frequently expressed their frustration over the lack of empty scows, and some dredge operators told EPA oversight staff that they were working slowly because, once the available scow was filled, they would have nothing to do for the remainder of their shift. While the Weekly Productivity Summary Reports did not provide estimates of the dredging hours lost due to these causes, they likely had a negative effect on dredging production rates. Overall, dredge production rates were impacted such that the initial dredge pass within every CU dredged during Phase 1 took greater than one month.

3.4.3 Delays Due to Scow Unloading and Coarse Materials Separation Process Problems

As noted in Table III-3-4, a shortage of empty scows at the dredge platforms caused significant delays in dredging throughout the season. Although the number of large hopper scows available appears to have been adequate for Phase 1, the scow unloading operation could not keep up with the dredges and dredges sat idle for many hours awaiting an empty barge. Information on barge unloading has been provided in Appendix P, Parsons Barge Data, and in Appendix N, Processing Facility Weekly Activity Reports, of the Phase 1 Data Compilation report (GE, 2009a).

The scow unloading process has been described in Section III 2. Unloading was conducted on a 24 hour per day, 7 day per week basis. The Parsons Barge Data report for the week ending October 31, 2009, summarizes the barge unloading data as follows:

- Total Number of Scows Unloaded 629
- Estimated Total Scow Solids Volume 265,094 CY
- Estimated Solids Unloaded Directly Into Trucks 132,947 CY
- Estimated Solids Unloaded to Trommel Screen 132,140 CY
- Estimated Average Scow Solids Volume 421 CY
- Maximum Barge Solids Volume 929 CY
- Estimated Total Scow Free Water Content (pumped out) 51,601,225 gallons
- Estimated Average Scow Water Content 82,037 gallons
- Peak Unloading Rate 7.4 CY per minute
- Average Time to Unload a Scow 3.9 hours

The estimate of the total scow solids volume, 265,094 CY, was based on observations of the level of sediment in the scows after free water had been removed and bucket counts by the dredge operators as the scows were filled. It is probable that some solids were entrained in the free water pumped from the scows. Nevertheless, the estimate is in relatively close agreement with EPA's estimate of 273,600 CY of in-situ solids dredged during the project, and this indicates that there is essentially no bulking of the sediment as it is dredged.

The average barge unloading rate has been estimated at 107 CY per hour (1.7 CY per minute) by dividing the average barge solids content, 421 CY, by the average time required to unload a scow, 3.9 hours. This is significantly less than the 333 CY per hour rated production capacity of the Komatsu excavator used for unloading. Furthermore, the average time recorded to unload a scow does not include the time required to remove an empty scow and maneuver a filled scow into place adjacent to the excavator, time lost due to equipment malfunctions or weather related delays. As shown in the Parsons Barge Data report, the lag time between barges varied from less than 0.5 hours to more than 3 hours and averaged around 1.5 hours. Delays due to equipment malfunctions, including problems with the remote controlled Bobcat excavator used to mound sediment in the barges as they are unloaded and problems with the trommel screen, are recorded in the Processing

Facility Weekly Activity Report, but no estimate of the time lost is given. Weather-related delays over the course of the Phase 1 project amounted to a relatively insignificant 30 hours.

A number of factors affected the rate at which scows could be unloaded. As noted in Section III 2, the efficiency of the Komatsu excavator dropped significantly when the depth of sediment in the barge fell below that required to completely fill the 5 CY bucket mounted on the machine. An examination of the scow unloading rates provided in the Parsons Barge Data report indicates that, when over 80 percent of the solids in the scow could be off-loaded directly into trucks, the unloading rate varied from about 240 CY per hour for scows containing 600 to 700 CY of solids but dropped to 90 to 150 CY per hour for scows containing 200 to 300 CY of solids. When 50 percent or more of the sediment in the scow was off-loaded into the trommel screen, typical unloading rates ranged from around 70 to 120 CY per hour for a scow containing from 600 to 700 CY of solids but dropped to 50 to 60 CY per hour for a scow containing 200 to 300 CY of solids.

The large hopper scows used for Phase 1 were designed to operate at drafts of up to about 11 feet. Ullage tables showing the approximate load carrying capacities of these scows at drafts of 1 to 11 feet are included in Appendix III-A. However, the dredging contractor limited the maximum draft to about 8 feet due to concerns about the stability of the large scows when carrying large volumes of free water. At this draft, the load carrying capacities are listed in the tables as 1488 tons for a box jumbo hopper scow and 1384 tons for a rake jumbo hopper scow. Assuming a unit weight of solids of 1.3 tons per CY, the load of the average scow containing 421 CY of sediment and 51,601,225 gallons (406 CY) of water was about 890 tons and the average draft was around 5 feet. Had all large hopper scows been loaded to a draft of 8 feet before transporting them to the unloading wharf, the number of scows unloaded would have been reduced by over one third, the amount of time lost at the wharf in removing empty scows and maneuvering loaded scows to the unloading station could have been reduced by about one third, the unloading rate achieved by the Komatsu excavator would have been substantially higher and the time lost by the dredge operators while awaiting an empty scow would have been reduced substantially.

The water depth in the areas dredged during Phase 1 restricted the draft available to the large hopper scows. This was particularly true when dredging in CU-1. The depth of water in one section of the navigation channel just downstream from this CU was only about 5 feet and the large hopper scows could only be loaded to a draft of between 3 and 4 feet if they were to cross over this shallow area without grounding. Although deepening the channel in this area would have permitted a more efficient operation by allowing hopper barges to be loaded to a deeper draft, it was not done until after dredging had been substantially completed in CU-2 and CU-3 due to shallow drafts in those CUs. The use of large hopper scows in the river along the west side of Rogers Island was also severely restricted due to the shallow depth of water in this channel.

Shallow draft mini-scows were employed for most of the dredging in this area, and the sediment was transferred to large hopper scows stationed in deeper water at a transfer point near the south end of the island.

The inability of the scow unloading operation to keep pace with the dredge production was also affected by problems encountered in the operation of the trommel screen and shaker screens used to separate coarse sediments from finer sediment that had to be dewatered using filter presses. Problems encountered with the trommel screen are listed in Appendix N of the Phase 1 Data Compilation report (GE, 2009a). Appendix N indicates that, until the end of July, the trommel could not handle a full, 5-CY bucket of sediment from the scow unloading excavator. In addition, the Weekly Facility Operating Reports note structural, mechanical and/or electrical problems with the trommel nearly every week and several problems with the shaker screens. However, these reports do not provide an estimate of time lost in unloading scows due to these problems.

Scows containing large quantities of clay caused difficulties at the unloading wharf and throughout the sediment processing facility. These problems were particularly evident during the last few weeks of dredging as the dredging contractor attempted to remove a thin layer of contaminated sediment lying immediately above an uneven, lacustrine clay surface. Although the dredge operators attempted to minimize the amount of clay removed with the contaminated sediment, many dredge buckets contained mostly clay.

Large balls of clay placed in the trommel screen were discharged with the trommel rejects. This material was frequently judged too wet to be merely transferred by truck to the coarse material staging area, so it was moved by bucket loader to a point adjacent to the scow unloading excavator and placed back into the trommel screen for a second or even a third attempt at breaking it into small enough pieces so that it would pass through the screen for processing by the hydrocyclones. Using the scow unloading excavator to re-process this clay slowed the scow unloading process and caused a further backup of filled scows at the unloading wharf. Furthermore, when the clay did pass through the trommel screen and hydrocyclone systems, the operation of the slurry thickening tank was adversely affected and the cycle times of the filter presses increased markedly. As a result, a decision was made to move the clay balls to the north wharf coarse sediment staging area where an attempt was made to reduce its water content by adding quicklime and mixing it with sand and gravel.

Once dredging began and it was found that scow unloading could not keep up with dredge production, it was very difficult to make any major improvements to the system without stopping the unloading operation altogether. However, a number of improvements were made to the scow unloading and coarse materials separation systems during the project, including adding a second pump system to remove free water from the scows, adjusting the amount of recycle water supplied to the trommel screen, installing cleanouts in the piping from the trommel screen discharge hoppers to the shaker screens to make it easier to clear periodic blockages in the pipes, and changing the trommel screen rotation speed. In addition, an attempt was made to unload scows using a solids handling pump, but this was found to be unsuccessful when wood debris in the sediment plugged the pump intake.

It is clear that the rate at which scows can be emptied at the unloading wharf had a significant impact on dredging productivity during Phase 1. Assuming that the volume of sediment that will be dredged in Phase 2 of the project is as shown in Table III-3-3, the unloading operation will have to average 2890 CY per day to meet the required seasonal dredging volume and 3210 CY per day to meet the target volume assuming that the scows are unloaded on a 7 day per week schedule (and dredging occurs on a 6 day per week schedule). On a peak day, the unloading rate would have to be considerably higher.

The design of the unloading system called for a capacity of slightly over 5000 CY per day, but this rate was never achieved. Changes in the unloading system will be needed to attain a rate commensurate with the required rate of dredging during Phase 2 if the production targets are to be met. These changes may include the addition of a second unloading excavator plus changes in the coarse materials separation screens or other changes to the unloading and coarse material separation systems.

3.4.3.1 Delays Caused by High River Flows

The dredging contract specifications and the Productivity Standard called for suspending dredging operations when river flows exceeded 10,000 cfs. Unusually high rainfall amounts were experienced between the middle of May and early July and resulted in abnormally high river flows. Furthermore, it was found that operating in the west channel at Rogers Island was difficult and dangerous at flows approaching 10,000 cfs, particularly in CU-9. Early in the season a large hopper scow ran aground in this channel when the tug boats couldn't control its movement. Accordingly, operations in the west channel were restricted to times when the flow was 7000 cfs or less. This restriction was later revised to 8000 cfs to 8500 cfs, depending upon location in the channel. High flows resulted in an estimated loss of 1090 hours of potential dredging time.

3.4.3.2 Weather Related Delays

Lightning storms and periods when fog restricted visibility and made the movement of vessels dangerous resulted in the loss of an estimated 382 hours of potential dredging production during the season.

3.4.3.3 Delays Due to High PCB Resuspension Rates

Dredging operations were suspended on two occasions during Phase 1 because of high PCB concentrations in the water column. On August 7, 2009, dredging was shut down at approximately 6:30 in the evening and did not resume again until August 11. A total of 919 hours of potential dredging time was lost during this period. On September 11, 2009, dredging was again suspended, but only in CUs 4 and 18 where the sediments contained high concentrations of PCBs. Dredging was resumed on that same day, but in only one of the two CUs rather than in both CUs simultaneously. An estimated 103 hours of dredge production time was lost as a result.

The potential impact of high PCB resuspension rates on dredging productivity during Phase 2 is of concern to EPA. As described in Chapter I, the mass of PCB resuspended in the water column exceeded the Resuspension Standard and, as noted above, was responsible for over 1000 hours of lost dredging time during Phase 1. While a number of factors that likely contributed to higher than anticipated resuspension rates have been identified, it is not clear which ones have the most effect or whether they can be controlled. This issue will continue to be investigated as the Phase 2 design is completed.

3.4.3.4 Delays Caused by Wood Debris

Wood debris, consisting primarily of slab wood disposed of in the river by saw mills, was encountered in portions of most CUs dredged during Phase 1 of the project. The presence of this wood in the sediment prevented the dredge buckets from closing fully, and time was lost as the dredge operator attempted to close the bucket before lifting it from the river bottom. In many instances where slab wood was encountered, complete closure of the bucket could not be achieved and sediment and water drained from the bucket as it was lifted above the water surface. This led to increased PCB resuspension rates and a reduction in the amount of sediment placed in the scow during each bucket cycle.

It is expected that slab wood debris will continue to be encountered during Phase 2 dredging in the Thompson Island Pool. Whether this debris is also present in any significant amount in River Sections 2 and 3 is currently unknown.

3.4.3.5 Delays When Dredging in Shallow Water

As noted in Section III 2, mini-scows constructed of Flexifloats with 2 foot high walls were used in shallow areas of the river. Nine of the 10 mini-scows available had capacities of about 35 CY if filled to the tops of their walls. However, at least one foot of freeboard had to be maintained in these scows in order to prevent free water from overflowing. They appeared to function reasonably efficiently when the sediments consisted of coarse sand and gravel and the depth of cut was such that the dredge bucket could be filled, or nearly filled, during each cycle. Under these conditions, the sediment could be mounded above the walls in the center of the scow. However, their capacity was severely reduced when dredging more fluid sediments and when the depth of cut was less than that required to fill the bucket, as each bucket of sediment contained a higher percentage of water. When the buckets contained large quantities of water, only about 25 CY of sediment could be placed in the mini-scow before they had to be moved to the transfer station and unloaded.

3.4.3.6 Delays Caused by Draining Free Water From Dredge Bucket

Very shallow cuts were generally implemented as dredging approached the design depth in a CU and the dredge operators attempted to meet the vertical cut tolerances specified in the dredging contract. Under these conditions, the dredge bucket usually contained as much or more water as it did sediment and the amount of actual sediment that could be placed in a mini-scow without overflowing its walls was reduced to around 25 CY. The filled scow was then moved to a transfer station where it was unloaded into a large hopper scow. If an empty mini-scow was not immediately available, the dredge operator was unable to work until the filled scow was unloaded and returned to the dredge.

In an effort to increase the volume of sediment placed in a mini-scow before it had to be emptied, the dredge operators were allowed to drain free water from a closed or partially closed bucket before emptying it into the scow. Draining the water from the bucket typically took from one to two minutes and increased the bucket cycle time significantly. This practice also increased the amount of PCBs lost to the water column and may have been partially responsible for the time lost in dredging due to high PCB resuspension rates.

3.4.3.7 Impacts Resulting from Quality of Life Standards

The concentration of PCBs in the air frequently exceeded the Air Quality Standards established for the project when dredges were operating in highly contaminated areas. To reduce PCB emissions from the scows, the dredging contractor was directed to maintain sufficient water in the scow to cover the sediment. In addition, in certain areas where dredging was conducted close to residences along the shore, the dredging contractor was also requested to maintain at least 5 feet of freeboard in the large hopper scows to minimize the impact of wind on the surface of the sediment and water. Maintaining 5 feet of freeboard had no effect on the amount of material that could be carried in the scows, however, as the available volume within the scow under this condition is in excess of 1500 CY. Scows filled with this amount of sediment and water would exceed the maximum draft figure of 8 feet established by the dredging contractor for stability purposes.

The steps taken to reduce PCB concentrations in air undoubtedly had some effect on dredge production rates. However, no estimate of the total hours consumed in adding water to scows or pumping this water out for treatment at the dewatering site is available, and it is believed that the overall impact on production rates was relatively minor.

3.4.4 Filter Press Operation

Data on the operation of the filter presses from the beginning of the project through October 17, 2009 can be found in Appendix N, Processing Facility Weekly Activity Reports, of the Phase 1 Data Compilation Report (GE, 2009a). According to these reports, 1340 press drops were produced at 22.2 CY each for a total of 29,748 CY of filter cake. Press cycle times varied considerably depending upon the characteristics of the sediment being dewatered and the solids content of the slurry being pumped into the presses. Cycle times as low as 2 hours and as high as 16 hours are listed in the reports but times from 2.5 to 4 hours are typical. The filter cake solids content was typically in the 60 to 70 percent range.

Based on the figures provided in the Processing Facility Weekly Activity Reports, an average of 111 drops was made by each of the 12 presses available over a 159 day period. This amounts to 0.7 drops per press per day. The average cycle time for a press was approximately 5 hours. Based on a press cycle time of 5 hours, each press could be expected to process at least 4 drops per day, or more than six times the average volume processed during Phase 1 of the project. Therefore, it appears that capacity of the filter presses is adequate for the volume of material expected in Phase 2. It may, however, be necessary to schedule dredging such that all dredges are not operating simultaneously in areas with high silt and clay contents.

3.4.5 Water Treatment Plant Operation

As noted in Section III 2, the water treatment plant has a total installed capacity of 2.16 mgd and a firm capacity of 1.44 mgd with one treatment train out of service. Between May 9 and October 31, 2009, the plant treated 87.75 million gallons of water from all sources for an average daily flow of

0.50 mgd. Of this amount, an average of 0.30 mgd came from the scow pump-out systems at the unloading wharf and 0.20 mgd came from rainfall on the site and other sources.

The maximum daily flow treated at the plant and discharged to the Canal occurred on August 22, 2009 and amounted to 1.375 million gallons. The maximum volume of water treated in any one week, as shown in the Weekly Productivity Summary Reports, was 6.35 million gallons, which is equal to an average daily flow of 0.90 mgd during that week. The maximum amount of water pumped from scows in any one week was 4.04 million gallons, which is equal to 0.58 mgd. Based on these figures, it appears that the water treatment plant has adequate capacity to treat the volume of water that will be produced in Phase 2 of the project. Even if the maximum weekly volume of water pumped from scows at the unloading dock were to double to 8.1 million gallons, the flow to the plant should not exceed its total installed capacity.

3.5 Backfilling and Capping Work

Backfilling and engineered cap construction work began on September 14 and ended on December 4, 2009. Backfill only was placed over approximately 31 acres where the target cleanup criteria were met, while engineered caps were constructed over approximately 17.3 acres where dredging failed to achieve the cleanup level. The backfilling and cap construction work began late in the season due, in part, to the under estimation of the depth of contamination and the resultant need to conduct multiple attempts to dredge to bottom of the contaminated layer in most CUs. As a result, more equipment was needed to complete this work than originally anticipated and it continued later into the season than desirable.

The total volume of backfill and cap material placed is estimated at approximately 155,000 CY while the area covered by backfill and/or cap was approximately 48 acres. The material was placed using five Cat 385 dredges with 5 CY open clamshell buckets, four Cat 320 dredges with 1 CY buckets, and one Cat 345 dredge with a 3 CY bucket. The Cat 385 and Cat 345 dredges placed the material by opening the bucket a predetermined amount and swinging the bucket in a slow arc over the water surface to create a thin layer of material on the river bottom, while the Cat 320 dredges placed the material at a point. The use of the bucket positioning systems on the excavators to control the location and rate of swing of the excavator arm and the opening of the bucket jaws as the backfill or capping material was installed appeared to work well. Backfill and capping material was placed to within the tolerances specified in the design without undue difficulty.

The rate of placing the backfill and cap material varied depending upon the machine used to place the material. The Cat 385 dredges each averaged about 72 CY per hour, the Cat 345 averaged about 43 CYY per hour and the Cat 320 averaged around 38 CY per hour. The number of dredges used to place the backfill and cap material varied from two at the onset of the work to eight in mid-November.

Some problems were encountered during backfill operations. During backfill placement in near shore areas in CU-17, it became apparent that the Type 1 backfill gradation was too fine to maintain the presumed stable slope of approximately 3H to 1V. Tests performed by GE at CU-17 indicated that Type 1 backfill tended to assume an angle of repose of approximately 4.5H to 1V to 6H to 1V. Based on these results, plans were revised such that many Type 1 near-shore backfill areas were first underlain with Type 2 backfill and then finished with Type 1 backfill to grade. It was agreed by GE and EPA that placing Type 1 backfill in all proposed areas would have resulted in the use of significantly more backfill. Furthermore, the relatively flat angle of repose produced by the Type 1 backfill raised concerns about its use in areas adjacent to NYSCC navigation channels. Review of the gradation and utility of Type 1 backfill is needed for Phase 2.

As a result of deeper than anticipated dredge cuts, the actual distribution of the additional 15 percent backfill, as indicated on record drawings, differs significantly from that proposed in the design (see Contract 4 plan sheets B0002-B0019). The original design called for approximately 17,561 CY, or 77 percent, of the 22,748 CY allotment of additional backfill to be placed in CUs 2 through 8, 17, and 18 if no additional inventory or residuals dredging passes were needed. The remaining 23 percent, or 5187 CY, was to be placed in CUs 9 through 11 and CUs 14 through 16. However, CUs 9 through 16 were not dredged.

Because dredging in some areas identified to receive this backfill extended to greater depths than anticipated in the design while bedrock was encountered above the design cut line in others, field changes had to be made in the amounts and locations where this material was placed. EPA guiding principles for the placement of the additional15 percent backfill, including a focus on first placing additional 15 percent backfill at primary submerged aquatic vegetation planting areas, were followed in making these field changes. Approximately 21,105 CY, or 93 percent of the allotted 22,748 CY, were actually placed in CUs 3 through 8 and none was placed in CUs 2, 17 or 18. Furthermore, only 7 percent of the original allocation was reserved for future use in CUs 9 through 16, which were not dredged. The adequacy of the additional 15 percent backfill allotment and overall approach to supporting submerged aquatic vegetation bed planting elevations should be reviewed and revised for Phase 2 in light of deeper than anticipated depths of contamination encountered during Phase 1.

3.6 Shoreline Stabilization and Riverine Fringing Wetland Reconstruction Work

It was originally anticipated that, where dredging was conducted up to the shoreline, temporary erosion control measures would be undertaken immediately by installing a wedge of stone, biologs, timber planks or other control measures. Inasmuch as additional passes of the dredge were required in most areas to remove inventory and residual sediments below the original cut lines, these temporary measures were delayed until dredging in nearly all CUs was completed.

In general, backfill placement crews attained the Phase 1 riverine fringing wetland backfill target elevation of approximately 118.5 feet; however, some problems were encountered in the installation of biologs along those areas of the shoreline where they were called for in the design. The original design called for jute mesh and biologs to be installed to serve as wave breaks and contain Type 3 backfill in riverine fringing wetland reconstruction areas. Deeper than anticipated depths of contamination resulted in deeper dredging in some of these areas and, consequently, the use of more backfill in the near shore areas. The stakes designed to hold the biologs in place were driven into loose backfill rather than more compact native sediments, and stakes driven into loose fill alone did not adequately secure the biologs. As a result, some biologs had to be restaked many times and, ultimately, sand bags filled with sand and gravel were employed to hold them in place. Alternative approaches to constructing wave breaks and installing biologs and geotextiles at riverine fringing wetlands should be investigated and appropriate revisions should be included in the design for Phase 2.

3.7 Habitat Replacement and Reconstruction

Replanting of submerged aquatic vegetation and riverine fringing wetland vegetation should be accomplished in the springtime to achieve a reasonable success rate for the plants. Therefore, this work was scheduled in the Phase 1 design for Spring 2010. The time required to accomplish this work will not be known until next year.

3.8 Rail Transportation and Sediment Disposal

The shipment and disposal of dewatered sediment encountered unexpected problems during Phase 1 and threatened to curtail dredging activities at one point in the project. Loading sediment on rail cars at the dewatering site began on June 10, 2009, and the first unit train left the site for the WCS landfill in Andrews, Texas, on June 24, 2009 and arrived at the WCS facility on June 29, 2009.

In early July 2009, GE notified EPA that structural modifications would be needed at the WCS rail car unloading platforms to enhance unloading productivity. The rail car unloading system was originally anticipated to consist of a railcar tipping unit that would dump the entire contents of a gondola into an off-road dump truck for transport to the landfill. However, the tipping system was not constructed. Rather, platforms were built to allow backhoe operators to see into the cars and the sediment was unloaded with the backhoes. The loading of sediment into railcars continued at the dewatering site while the structural problems were investigated, but the loaded cars were held in Fort Edward until the problem could be resolved. On or about July 15, GE was advised that rail car unloading would resume but that unloading an 81-car unit train would probably take from 4 to 5 days rather than the 2 days originally projected.

On July 6, EPA Region 6 conducted an inspection of the WCS railcar unloading and cleaning operation. Following this inspection, EPA directed that the empty railcar weep holes be plugged and that the cars be covered with tarps for their return trip to Fort Edward. This requirement was not in accordance with the procedure agreed upon between GE and EPA Region 2. GE questioned this directive and all rail shipments of contaminated sediment ceased until an alternative cleaning procedure could be worked out and approved. This occurred in early September and, on September 9, 2009, the next shipment of sediment left Fort Edward for the WCS facility.

Between July 6 and September 9, the volume of dewatered sediment stored at the dewatering site increased steadily. To avoid stopping the project, additional coarse material storage space had to be developed. A temporary staging area was constructed for this material north of the unloading dock.

Once rail shipments resumed in early September, seven unit trains filled with 75,388 tons of sediment were shipped to the disposal site in a 32-day period. The average amount of sediment carried by each train was 8376 tons. However, on October 27, 2009, GE was notified by WCS that the pile of sediment in the disposal cell had experienced a slope failure and that unloading of railcars at the facility would have to stop until the pile could be stabilized. At that time there were three unit trains containing Hudson River sediment at the WCS facility. Rail car loading continued at Fort Edward until all available cars were filled. No additional trains left Fort Edward, however, as there was limited siding space available at the disposal site.

The shipment of dewatered sediment to the WCS facility resumed on December 19, 2009. Another unit train left Fort Edward on December 21, and a shipment of 29 additional gondolas filled with sediment occurred on December 23, 2009. However, the rate at which rail cars were being unloaded at the WCS facility was reduced significantly, and no empty cars were available to load at Fort Edward. Furthermore, there was concern that sediment would freeze in any railcars staged at the Fort Edward rail yard over the winter. Accordingly, shipments were discontinued for the winter.

It appears that rail cars can be loaded and dispatched from Fort Edward at a rate sufficient to handle the estimated volumes of sediment to be dredged each year in Phase 2. Problems with unloading and disposing of the sediment at the disposal site in Texas prevented compliance with the Productivity Standard requirement that all sediment be removed from the dewatering site prior to the end of the calendar year. A reliable disposal site with adequate capacity to receive and unload sediment shipped from Fort Edward is essential if Phase 2 is to be completed in accordance with the Productivity Standard. Consideration should be given to using two separate disposal sites so that shipping does not have to stop completely in the event of a problem at one site. At least one site should have a railcar tipping facility, as originally proposed for the disposal site used during Phase 1, to speed unloading and reduce the effort required to clean cars prior to their return to Fort Edward.

4 PROJECT IMPACTS ON CHAMPLAIN CANAL

4.1 General

Dredge and sediment transportation during Phase 1 had some impact on normal recreational and commercial traffic on the Champlain Canal, but the magnitude of this impact is difficult to quantify. With the exception of CUs 17 and 18, most areas of which are outside the navigation channel, the Phase 1 dredging was confined to the east and west channels along Rogers Island. Recreational boats were restricted from entering the channel east of Rogers Island to two half-hour periods each day, and only a few vessels were seen at the Fort Edward Yacht Basin during the summer. Dredging in the river west of Rogers Island is thought to have had little impact on boaters as few recreational boaters usually enter this area.

4.2 Lock 7 Operations

Much of the recreational boating traffic on the Champlain Canal in the Fort Edward area passes through Lock C7 (also referred to as Lock 7) on its way to Lake Champlain to the north and Albany or the Erie Canal to the south. There was some concern during the design of Phase 1 that recreational traffic through Lock 7 might cause delays for project-related vessels moving from the dredges to the dewatering site or that project-related use of this lock might have a significant impact on recreational use; however, no complaints were received by EPA from recreational users of the system during the project, and the lock functioned smoothly throughout the season. No unusual backup of traffic was noted at this lock.

The NYSCC maintains daily records of all vessels passing through a lock. The data for Lock 7 in 2009 are shown in Appendix III-C. Analysis of these data indicates that there were a total of 3697 project-related and 1657 other vessel lockages at Lock 7 between May and October as shown in

Table III-4-1. The numbers shown in the Table are the numbers of vessels passing through the lock, and not the number of times the lock was filled and emptied. A scow accompanied by two tug boats is counted as two vessel lockages, not three, as only registered vessels are counted.

August was the peak traffic month at Lock 7, when 1242 vessel lockages were reported. A review of the NYSCC daily records for this month indicates that the lock was filled or emptied a total of 722 times during the month for an average of 23.3 times per day.

The greatest number of project-related vessels passing through the lock in any month occurred in August. In that month, 776 project-related vessels, not counting scows, passed through the lock for an average of 25 per day. A review of the project barge operations data (i.e., Parsons Barge Data, Appendix P of the Phase 1 Data Compilation Report; GE, 2009a) indicates that 132 scow-loads of sediment passed through Lock 7 in August on the way to the unloading dock for an average of 4.3 scows per day. These scows subsequently returned through the lock after being unloaded. Assuming that each scow was accompanied by two tug boats, these scows accounted for approximately 17 of the 25 average daily project-related vessel lockages that occurred in August.

The peak traffic day at Lock 7 occurred on August 6, when the lock was filled or emptied a total of 34 times. The time required to fill or empty the lock is approximately 10 minutes, and it typically takes another 10 to 15 minutes or so for vessels to enter the lock, tie up and exit during a passage. Thus, the total lockage time for a vessel or vessels to pass through the lock is typically from 20 to 25 minutes. Lock 7 was operated 24 hours per day during the active dredging season and could have accommodated many more passages than occurred on the peak day. Even if the average passage time were estimated at 30 minutes, it could have accommodated up to approximately 48 lockages per day or about 14 more than occurred on the peak day. Thus, the capacity of the lock should be adequate for the production rates anticipated in Phase 2 without causing undue interference with normal canal traffic.

The Parsons Barge Data lists the volume of each of the 132 scows unloaded each day. During August, the average scow carried approximately 490 CY of solids and 440 CY of free water. Assuming that the solids had a unit weight of 1.3 tons per cubic yard and the water weighed 0.84 tons per cubic yard, the average scow load amounted to 1077 tons, or approximately 78 percent of the tonnage that can be carried by a rake hopper scow loaded to a draft of 8 feet. The largest scow load contained 856 CY of sediment, and at least 18 loads carried in excess of 700 CY of solids.

Assuming that the average scow carries 700 CY of sediment during Phase 2 and that dredging production averages 3200 CY per day, an average of 4.6 scow loads of sediment will pass through the lock each day which is only slightly more than the 4.3 loads per day average experienced during August in Phase 1. The lock should not have any difficulty handling this slight increase in scow loads during Phase 2 of the project.

4.3 Phase 2 Impacts on Boat Traffic

During the first year of Phase 2 of the project, dredging is planned to take place near the entrance to Lock 7 and may have some impact on recreational boating. Provision will have to be made in the design to permit vessels to pass through the dredging areas without unreasonable delay.

The river is not navigable between the Thompson Island Dam and the Fort Miller Dam; however, remediation is scheduled for this non-navigable section of the river. The navigable canal, adjacent to the non-navigable section of the river, passes through a 75-foot wide land cut constructed around these two dams and ending at Lock 6. Dredged material from the non-navigable section of the river will be transferred, by crane or other mechanical means, into scows moored in the canal land cut. Although remediation of contaminated sediments is currently not planned for the land cut section, some dredging will be necessary to widen the canal so that vessels will be able to safely pass the scow loading operation.

As dredging proceeds in River Sections 2 and 3, sediment will have to be transported greater distances and more locks will have to be transited. The scows will have to be filled to their maximum stable draft to minimize the number of trips needed to complete the work and to avoid impacts on non-project-related canal traffic. In addition, more scows may be needed to compensate for the long travel times, particularly when dredging in River Section 3.

If properly managed, Phase 2 should have little effect on normal canal traffic. However, a comprehensive, quantitative analysis should be conducted of lock usage versus capacity for the affected locks to identify any potential problems and develop mitigation plans if needed.

5 Summary of Findings, Conclusions and Recommendations

5.1 General

One objective of the Phase 1 dredging was to demonstrate the capability of the dredging and sediment processing systems to meet the Productivity Standard. This demonstration was generally successful in that it showed that the mechanical dredging method selected by GE could successfully remove the sediment from the river and that most of the unit processes at the sediment processing and dewatering facility functioned as designed. While Phase 1 did not show conclusively that the current design could successfully dredge and process sediment at the rates anticipated for Phase 2 of the project, it identified those aspects that are inadequate and that, if corrected before Phase 2 begins, should allow the project to meet productivity targets.

A summary of the major conclusions arrived at during the evaluation of Phase 1 work is presented below, along with recommendations for addressing identified problem areas. It should be noted that all except the last two of these recommendations are related to improvements in design and operation rather than to proposed changes in the Productivity Standard. The recommendations, if followed, should eliminate a number of the more significant impediments to meeting the Standard that were identified during Phase 1.

5.2 Sediment Volume Remaining to be Dredged

The total volume of contaminated sediment remaining to be dredged is not known with certainty. The Phase 1 design consistently underestimated the depth of dredging needed to reach the 1 mg/kg total PCB concentration horizon in the sediments in all CUs that were dredged. As a result, numerous dredging passes had to be completed in nearly all CUs and a significant amount of time was lost to additional mapping, sampling, and re-defining dredge cut lines.

A sound estimate of the total volume of sediment likely to be removed from the river during Phase 2 is needed to fully evaluate the ability of the dredging and sediment processing design to remove, dewater, and dispose of the material. Thus far, the sediment volume has been estimated at 2,650,000 CY. A limited amount of additional sampling work is recommended to refine estimates of DoC, particularly in areas where a majority of previous core samples were incomplete, and should be started as soon as possible. It does not have to be done for all Phase 2 dredge areas prior to beginning the Phase 2 work, but can be completed in stages prior to each year's dredging season. In the event that additional sampling in those areas slated for dredging during the first year of Phase 2 cannot be completed during early Summer 2010, the dredging cut line should be adjusted approximately 9 inches below the current design surface, based upon the results of the Phase 1 dredging (see Chapter II).

5.3 Phase 1 Dredging Productivity

EPA estimates the actual amount of contaminated sediment dredged during Phase 1 at 273,600 CY based on a comparison of 2009 pre-dredging and 2009 post-dredging bathymetric surveys. This exceeds the 265,000 CY target amount established in the Productivity Standard for Phase 1. (GE has arrived at a slightly larger volume.) The maximum amount dredged in any one month period during Phase 1 is estimated at approximately 77,000 CY (GE estimated 78,000 CY). This is less than the estimated 86,420 CY per month average productivity rate required to dredge an estimated

475,300 CY from the river during each season of Phase 2. Had empty scows been available, dredging production would likely have exceeded the rate required to meet Phase 2 targets.

Scows frequently could not be loaded to full capacity during Phase 1 due to shallow drafts. In some CUs, access dredging was not performed to address this constraint until a significant amount of dredging had been completed. In the interest of expediting inventory dredging production rates in Phase 2, wherever access dredging is needed for dredging in a CU, it should be accomplished prior to any inventory dredging in that CU to facilitate efficiency in both dredging and closure.

The design specifications (Contract 4, Specification Section 13801 3.01 A) limited inventory dredging to a maximum of two contiguous CUs. During Phase 1 operations, GE requested a revision to this requirement to permit opening a third CU when inventory targeted by the design has been completed in the first CU, and only clean-up dredging remains [letter from Timothy Kruppenbacher (Operations Manager) to David King (Director of EPA's Hudson River Field Office), July 2, 2009; see Common Appendix]. EPA concurred with GE's reasoning that this revision would enhance productivity and would not cause significant re-contamination of the downstream CU (minimal downstream transport of sediments would be captured in that CU). This request was approved by EPA with the stipulation that closure occur sequentially from upstream to downstream. Based on the experience in Phase 1, EPA concludes that dredging should be allowed in the number of contiguous CUs required by the logistics of working with multiple dredges in a navigable waterway, as determined during the design of each year's work, with the stipulation that closure should occur sequentially from upstream to downstream. Backfilling and other closure work should begin as soon as possible after dredging in a CU is completed to reduce the number of CUs that are open at any one time and potentially contributing to resuspension.

5.4 Dredging Season

The Phase 1 actual dredging work extended from May 15th to the end of October, a 165-day period. Backfilling and shoreline stabilization work continued through November and into the first few days of December. Thus, Phase 1 work on the river lasted a total of about 200 days. Assuming that dredging can begin on or about May 1 and be conducted through at least October 15 in an average year, and backfilling and shoreline stabilization work can be completed by November 1, a total average season of approximately 180 days, including 165 days of dredging followed by an additional 15 days of backfilling and shoreline work, should be possible in Phase 2. Demobilization of the dredging plant and preparing the sediment processing site for winter should begin as soon as the last scow loads of contaminated sediment are unloaded in mid- October. Demobilizing the backfilling and shoreline stabilization equipment would occur during the first two weeks of November and be completed by November 15, the average date that canal locks close for the winter.

5.5 Dredging and Sediment Transport

A significant amount of productive dredging time was lost as dredge operators attempted to meet the tight (*i.e.*, ± 3-inch) vertical tolerances specified for the dredge cut in the design. Furthermore, accepting a cut up to 3 inches less than that required to achieve the 1 mg/kg Total PCB horizon in the river bed, assuming that this horizon can be adequately defined in the design, is likely to lead to a need for additional dredging passes to meet the Residuals Standard. Based on the experience gained in Phase 1, the Phase 2 design should require dredging at least to the projected 1 mg/kg Total PCB horizon and an overcut of 6 inches, based on revised dredge cut lines. That overcut should be extended to 9 inches in areas where existing cut lines must be used. This should increase production by reducing bucket cycle times and minimizing the need for thin layer residual dredging passes.

Consideration should be given to changing the dredging implementation and approval procedure used by GE in Phase 1. This procedure involved (1) contractor dredges to the design cut line, (2) contractor conducts a bathymetric survey to confirm that the cuts are within the tolerances specified, (3) contractor conducts fine grading to correct for areas where the cut line is slightly high, (4) contractor notifies GE that the design cut elevation has been achieved, and (5) GE directs a third party surveyor to conduct a bathymetric survey to confirm this fact before residuals samples are collected. Fine grading prior to sampling was very time-consuming and was of little or no value in those instances where the residual sampling results showed that the contamination extended well below the design cut line. If residual sampling were conducted as soon as dredging meets the design cut line, as shown by the dredging contractors control surveys, and the core samples were immediately analyzed over a range of depths rather than initially analyzing the uppermost 6 inches of the sample as was done during the early stages of Phase 1, those areas where the design cut line was set too high could be immediately identified for additional production dredging to remove inventory, and fine grading would be done in only those areas where the removal of a shallow layer of residual sediments is needed. If the dredging contractor is also allowed some overcut beyond the design cut line during inventory dredging, the amount of time consumed in fine grading to achieve a tight design tolerance around the cutline would be minimized.

The presence of slab wood and other debris in the sediment frequently prevented the dredge bucket from closing, and time was lost while attempting to achieve closure. The availability of heavy duty, environmental buckets capable of shearing through the wood and closing more frequently should be investigated. Furthermore, since the experience gained during Phase 1 indicates that the mixture of slab wood and sediment encountered is almost always contaminated, the contractor should be directed to dig to the bottom of any debris field, if this extends past the design cut line, before residual sampling is conducted.

Draining free water from closed dredge buckets prior to placing their contents into mini-scows was permitted during Phase 1 to avoid filling these scows with water and causing an unstable condition for the vessel. Draining free water increased bucket cycle time by up to a minute or more and added to the amount of PCB released to the water column. Draining free water from buckets held above the water surface should be prohibited during Phase 2. The sediment and water gathered in each bucket bite should be immediately placed in the scow. If excessive amounts of water in mini-scows delays dredging substantially, consideration should be given to transferring the excess water by pump and floating pipeline to a large hopper scow or a separate, tanker barge with capacity to handle the water.

During Phase 1, the average volume of solids carried in a large hopper scow was 421 CY. This is considerably less than could have been carried if the scows had been loaded to a draft of 8 feet. The maximum volume of solids recorded in a scow was 929 CY. The dredging contractor should be directed to fill scows to near their maximum capacity during Phase 2 to reduce the number of scows that pass through the locks, improve scow unloading times, and reduce vehicle traffic which contributes to PCB resuspension.

5.6 Backfilling

5.6.1 Near-shore and 1-Foot Backfill Placement

During backfill placement at CU-17 it became apparent that Type 1 backfill consisted of too fine a gradation to maintain the assumed stable slope of approximately 3H to 1V. To achieve stable slopes, many Type 1 near-shore backfill areas were first underlain with Type 2 backfill and then finished with Type 1 backfill to grade. The gradation and utility of Type 1 backfill should be reviewed and appropriate changes made in the Phase 2 design to avoid the need to place this backfill in two separate lifts.

5.6.2 Additional 15 Percent Backfill Placement

The Phase 1 design contained an allocation of 22,748 CY of additional 15 percent backfill and called for placing this material in 15 of the 18 CUs scheduled for dredging. Approximately 17,561 CY (77 percent) of the additional 15 percent backfill allotment was to be placed in the nine CUs actually dredged in Phase 1 if no residuals dredging passes were needed. These CUs were CUs 2 through 8, 17, and 18. However, dredging in many areas extended to much deeper depths than anticipated in the design. As a result, the amount of backfill needed to bring the river bed up to a design depth within the light penetration zone to support new submerged aquatic vegetation growth would have consumed more material than allotted under the additional 15 percent additional backfill agreement. In an attempt to make use of the limited supply of backfill available under this agreement in a manner that would provide for the reestablishment of the submerged aquatic vegetation over the largest area possible, the locations selected for placing the backfill were revised in the field.

Approximately 21,105 CY of the allotted 22,748 CY were actually placed in CUs 3 through 8 and no additional 15 percent backfill was placed in CUs 2, 17, or 18. The volume of backfill placed in portions of CUs 5 and 6, where bedrock was encountered above the design dredge cut line, was reduced by agreement between GE and EPA to avoid raising the river bottom elevation above the pre-dredging elevation and to preserve material for use in other areas.

EPA guiding principles for the placement of additional 15 percent backfill, including a focus on first placing additional 15 percent backfill at primary submerged aquatic vegetation planting areas, were followed. The volume of material placed in CUs 3 through 8 represents approximately 93 percent of the volume allocated as opposed to the 77 percent anticipated during the design. Thus, only 7 percent of the original allocation remains for future use in CUs that were not dredged.

In summary, only 6 of the 15 CUs where additional 15 percent backfill was to be placed in accordance with the original design actually received any of this material, and the volume reserved for future use in CUs that were not dredged is very limited. The adequacy of the additional 15 percent backfill allotment and overall approach to supporting submerged aquatic vegetation planting bed elevation zone attainment should be reviewed for Phase 2 in light of deeper than anticipated contamination encountered during Phase 1. This review should be done once submerged aquatic vegetation planting bed areas are identified for Phase 2 and should take into account the uncertainties in predicting the final elevation of the river bed in advance of actual dredging.

5.6.3 Type 3 Backfill Placement and Riverine Fringing Wetland Reconstruction

In general, backfill placement crews attained the Phase 1 riverine fringing wetland backfill target elevation of approximately 118.5 feet. Original designs appear to have assumed that biologs and jute mesh would be staked into native sediments underlying backfill; however deeper than anticipated depths of contamination resulted in deeper backfill, and stakes driven into backfill alone did not adequately secure the biologs. This resulted in the need to repair and replace biologs in some locations as the dredging season came to a close. Alternate approaches to the riverine fringing wetland offshore biolog/wave break and other geotextile installations should be considered and appropriate changes should be made in their design for Phase 2 to avoid the need for and delays associated with this work.

5.7 Shoreline Stabilization and Reconstruction

In general, a more flexible suite of shoreline stabilization measures is needed that reflects a wider range of shoreline and bank stability, potential flows/velocities, segment positions, sediment types, slopes, and vegetation status. Shoreline stabilization measures should be carried out as soon as possible following dredging in a CU rather than waiting until the end of the season as occurred during Phase 1.

5.8 Sediment Dewatering Facility Performance

The inability to unload sediment from scows at a rate sufficient to keep up with the dredges significantly reduced dredging productivity during Phase 1. Changes in the scow unloading and coarse materials separation systems are essential to meet Phase 2 production rates. Consideration should be given to adding a second unloading station at the sediment processing site wharf and using shaker screens instead of a trommel screen for initial separation of coarse sediments from those that must be dewatered by filter press.

The handling of large quantities of clay sediment at the sediment processing facility caused problems with unloading, with sediment thickening, and with filter press cycle times. Clay balls removed by the trommel screen or any other coarse screening operation should not be broken up to pass through the screening system but should be handled separately. Consideration might be given to air drying clay balls on a drying bed constructed with a layer of sand with underdrains to collect and remove water during the warm summer months or mixing the clay with well-drained sand and gravel, quicklime or a combination of these materials to stabilize it.

The filter presses and water treatment plant appear to have worked as designed during Phase 1 and are judged to have adequate capacity to meet the productivity requirements of Phase 2.

5.9 Rail Transportation and Disposal of Dewatered Sediments

Regulatory issues related to cleaning railcars at the WCS disposal site in Texas prior to their return to the sediment processing facility at Fort Edward, an inability of the disposal site operator to unload the gondolas in a timely fashion, and a slope failure at the disposal site all contributed to serious problems in shipping and disposing of sediments at a rate necessary to comply with the Productivity Standard. Consideration should be given to using two separate disposal sites so that shipping does not have to stop completely in the event of a problem at one site. At least one site should have a railcar tipping facility, as originally proposed for the disposal site used during Phase 1, to speed unloading and reduce the effort required to clean cars prior to their return to Fort Edward.

5.10 Recommended Revisions in the Productivity Standard

5.10.1 Revision Regarding Volumes that Count toward Target and Required Production

As noted in Section III 1.3 above, the Productivity Standard, as originally written, did not count sediment volumes removed during residual dredging or when dredging missed inventory towards required and target volumes. EPA recommends that the wording of the Standard should be changed to read, "The volume removed each year will be calculated on an in situ basis by comparison of before and after dredging bathymetric survey data. The volume to be counted toward achieving required and target volumes will include the volume targeted for dredging in the approved design and actually removed plus any volume dredged to remove residuals, missed inventory, side slopes, over cut allowances, and material dredged for navigational and restoration purposes. Sediment that may be dredged but that will not count toward meeting the required and target volumes will include any additional material removed to facilitate cap construction.

5.10.2 Addition of Provision to Extend Time Frame for Phase 2 at Discretion of EPA

EPA recommends that a provision allowing EPA to extend the time frame for Phase 2, at its discretion, be added to the Standard. This change would allow EPA to adjust the project schedule if necessary to accommodate conditions beyond the control of EPA and GE, such as extreme river flows, force majeure, or the discovery of significant additional inventory to be removed. The project will still be required to meet a PCB load threshold based upon the amount of mass to be removed and protection of the Lower Hudson River.

Chapter III References

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CHAPTER IV
PROPOSED CHANGES TO THE PERFORMANCE STANDARDS

CHAPTER IV – PROPOSED REVISIONS TO THE ENGINEERING PERFORMANCE STANDARDS

1 SUMMARY OF RELATIONSHIPS BETWEEN STANDARDS DURING PHASE 1

1.1 Underestimated Depth of Contamination

While 8 of the 18 CUs originally planned to be addressed in Phase 1 were not dredged in the 2009 season, a greater volume of sediment was dredged in Phase 1 than planned. This occurred because the design cut lines in every CU underestimated the true depth of contamination required to be removed in accordance with the ROD. Overall, if design volumes are adjusted for necessary setbacks adjacent to structures and for managing sediments at the shoreline, the amount dredged in the 10 CUs addressed in Phase 1 was nearly double the originally planned volume, and some contaminated sediment inventory that otherwise should have been removed was capped in place due to the impending closing of the Champlain Canal locks at the end of the season. This underestimation of the depth of contamination (or DoC) had a profound effect on the conduct and outcome of Phase 1 with respect to all 3 performance standards.

With respect to the Residuals Standard, it meant that in most CUs, subsequent dredging passes after the first were still targeting inventory in many locations, rather than residuals. On average, the first dredging pass removed only 49 percent of the actual sediment inventory by volume, and only 58 percent of the actual inventory by PCB mass. If the DoC had been correct for the design, the first pass would have been more efficient and would have removed a significantly larger portion of the volume and the PCB mass. While the Residuals Standard was designed to identify and target inventory missed during design, the sheer scope of the underestimation interfered with expeditious closure of CUs. Every CU required at least 3 dredging passes in some of its area, while 3 CUs required a maximum of 4 dredging passes and inventory remained in CU-1 after 5 dredging passes. See Figure IV- 1 which shows the number of dredging passes by CU, and also shows that concentrations consistently remained high at the surface for areas to be re-dredged in subsequent passes.

The fact that surface concentrations in targeted material remained high across the dredging passes indicates that inventory, rather than residuals, was generally being discovered by post-dredging cores. The complete actual depth of inventory was removed on the first dredging pass in just 36 percent of the total CU area dredged. On average, CUs were open for 130 days from the commencement of dredging to the completion of backfill or capping. Depending upon the particular CU, the first dredging pass required from 25 days to 74 days of active dredging (with an average of 43 days), while active dredging for subsequent passes lasted from 1 days to 28 days (with an average of 7 to 18 days, generally decreasing in length from pass to pass in a given CU, consistent with generally decreasing surface area by pass). Ultimately, the lengthy CU dredging durations impinged on the impending fall canal/lock closure and 25 percent of the area dredged in Phase 1 was closed by capping out of conformance with the Residuals Standard.

Conformance with the Productivity Standard was also affected by underestimated DoC because dredging in smaller cuts required more passes, more episodes of fine grading to meet tight tolerances with less efficient bucket use, more post-dredging sampling events and more time spent moving dredges from one place to another than would otherwise have been experienced. Had dredging been performed in fewer passes with more efficient (but well-controlled) use of the buckets (especially the 5-CY buckets), it is likely that additional CUs could have been dredged, or that at least dredging in more CUs could have been completed and those areas closed in conformance with the Residuals Standard.

Conformance with the Resuspension Standard was also affected by the need for multiple re-dredging passes associated with the repeated discovery of additional inventory. Based on preliminary multivariate analyses of the daily process and water column data, it has been found that water column PCB concentrations are positively associated with several factors, all of which would be expected to influence release and resuspension of PCB contamination, including bucket counts, volume removed, mass removed, flow rate, project vessel traffic, the number of CUs being backfilled in any given day, the area and concentration of freshly disturbed sediments in CUs open to the water column each day, bucket fill-rate and other surrogates to sediment spillage, among others. Some of these variables are directly or indirectly related to the number of passes required to remove the inventory.

The mechanisms associated with increased water column PCB concentrations are varied, and likely many, and should not be simplified to mere proportionality to mass removed, as suggested by GE. Mass removed is a surrogate for the net effect of all of the processes involved in dredging, and therefore correlates well with water column PCB concentrations. Thirteen of the 28 process variables considered demonstrated statistically significant positive associations with water column PCB concentrations. While the levels of association are individually weak indicating that no single process can be identified as "*the source*" of resuspension, a complex set of interactions among processes appears most likely to be "*causative*." If DoC had been more accurately estimated or if the uncertainty in DoC had been accounted for in the dredging design, inventory unknowingly left for later dredging passes could often have been removed in the first pass with more efficient cuts. Since multiple dredging passes to remove a particular amount of inventory necessarily involves more occurrences of resuspension-causing processes, it follows that optimizing dredging efficiency (with controlled bucket bites) should have resulted in less resuspension.

1.2 Scow Availability

Based on information provided by GE, the total time that all dredges working on the project were available and ready to dredge amounted to 18,125 hours over the entire season. This represents the total number of hours available to dredge (fully staffed and fueled, ready to dredge), not the number of hours that dredging actually took place (somewhat less), nor the number of hours that dredges were present at the project (much larger). Of 18,125 available hours, an estimated 10,878 hours (or 60 percent) was spent in active dredging, while the estimated total available dredge production time lost amounted to 7247 hours, or about 40 percent of the time that dredges were available to work.[1]

As shown in Figure IV-2, out of the 18,125 hours available for dredging, an estimated 382 hours (2 percent) were lost due to lightning storms, fog or other inclement weather conditions, 1022 hours (6 percent) due to concerns about high concentrations of PCB in the water column, 1090 hours due to high flows (6 percent), and 4753 hours (26 percent, and by far the largest fraction of the total lost hours) were lost due to a shortage of empty hopper scows.

A shortage of empty scows at the dredge platforms caused significant delays in dredging throughout the season. Although the number of large hopper scows available appears to have been adequate for Phase 1, the scow unloading operation could not keep up with the dredges and dredges sat idle for many hours awaiting an empty barge. Loaded scows arriving at the wharf were moored adjacent to a pump-out station where free water was removed. (Because the pumps require a head of approximately 1 foot of water over their inlets, they were not capable of removing all of the free water from a scow.) The scow was then repositioned adjacent to an excavator with a 5-CY bucket to remove the sediment. In order to maintain unloading production as the depth of sediment remaining in the scow fell below the efficient cutting depth of the bucket, a smaller remote-controlled excavator was lowered into the scow to push the sediment into a pile. For these reasons, scow unloading exerted the greatest limitation on the availability of scows. Because dredging typically did not occur on Sundays but scow unloading continued, scows tended to be more readily available at the beginning of the week, while not being available in sufficient numbers later in the week. This resulted in declining productivity over the course of the week.

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[1] GE's compilation lists 779 hours of available time lost as dredge operators attempted to remove a thin layer of sediment overlying an uneven clay surface. However, since these hours were actually spent in dredging, albeit at a slow rate of production, they have not been included in a summation of "lost" time.

The shortage of scows affected the speed at which CUs were dredged and added to the time that CUs remained open. As discussed above in "underestimated DoC", the length of time that a CU was open is a contributing factor to resuspension. Waiting for scows caused dredge operators to dredge less efficiently since they needed to occupy the time before the next empty scow arrived.

1.3 Exceeding Resuspension Criteria

Exceeding the resuspension criteria on three occasions during Phase 1 resulted in project shut downs which accounted for the loss of 1,022 dredging hours (hours when dredges were available and ready to work), which is about 6 percent of the total time when dredges were ready to dredge. This had a direct impact on project productivity which was about equivalent to the impact of shut downs due to high flow in the river.

The Resuspension Standard seasonal PCB load control levels for both Total PCB (117 kg) and Tri+ PCB (39 kg) were exceeded at all of the downstream monitoring stations. Between May 15 and November 30, 2009, the cumulative load at Thompson Island of 437 kg was about 1.5 times higher than the load at Lock 5 (269 kg/yr) and about 3 times higher than the export Total PCB to the Lower Hudson at Waterford (151 kg/yr). While elevated, the 437 kg estimated load for Thompson Island is small relative to the mass of PCB removed (20,000 kg). Tri+ PCB cumulative loads estimated for Lock 5 (123 kg/yr) and Waterford (61 kg/yr), exceeded the Control Level of 39 kg. However, the cumulative loads of Total PCB at Waterford, which is the station of importance with respect to downstream impact, did not exceed 1 percent of the mass removed during Phase 1 (*i.e.*, 200 kg for Total PCB, and 70 kg for Tri+ PCB).

2 PROPOSED CHANGES TO THE STANDARDS

Proposed changes to the Engineering Performance Standards are presented on Table IV-1. Table IV-1 presents a summary of the major proposed changes, associated numerical criteria, the rationale behind the changes and expected interaction with other standards.

2.1 Summary of the Proposed Phase 2 Resuspension Standard Criteria

Table IV-2 is the proposed Resuspension Standard Summary Table for Phase 2, and includes the proposed changes to the standard's numerical criteria.

2.2 Summary of the Proposed Phase 2 Residuals Standard Cases and Criteria

Table IV-3 is the proposed Phase 2 Residuals Standard Summary Table for Phase 2. The proposed Phase 2 Residuals Standard flow chart is presented as Figure IV-3.

2.3 Summary of the Proposed Phase 2 Productivity Standard Targets and Required Volumes

The productivity standard has been revised based on the current estimate of sediment volume for Phase 2. This estimate, and hence the standard's productivity criteria, should be updated as Phase 2 progresses to reflect findings derived during Phase 2 activities. The current productivity targets are:

Required volume:

Yrs 1 to 4:	475,300 CY/Yr
Yr 5:	475,300 CY*
Avg. daily volume:	3,378 CY
Avg. monthly volume:	86,420 CY

Target volume:

Yrs 1 to 4:	528,100 CY/Yr
Yr 5:	264,100 CY*
Avg. daily volume:	3,745 CY
Avg. monthly volume:	96,020 CY

*or remaining inventory

2.4 Anticipated Relationships between Revised Standards during Phase 2

The relationships and anticipated interactions between standards in Phase 2 are presented in Table IV-4.