Site: Centredale
Break: 3.7
Other: 27810

WORK PLAN

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

CENTREDALE MANOR RESTORATION SUPERFUND PROJECT SITE NORTH PROVIDENCE, RHODE ISLAND

Submitted to:

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U.S. Army Corps of Engineers
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HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT WORK PLAN

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Attachment B	Benthic Invertebrate Community Survey and Habitat Assessment
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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) Region I and U.S. Army Corps of Engineers (USACE) are conducting a Human Health Biota Consumption Risk Assessment and a Baseline Ecological Risk Assessment for the Centredale Manor Restoration Superfund Site located in North Providence, Rhode Island (Site). This effort is being performed under Contract No. DACW33-96-0005, Delivery Order No. 0059. A site map is provided as Figure 1.

This Work Plan has been developed to reflect the goals and objectives discussed and agreed upon during meetings with USEPA, USACE, Battelle, and Harding ESE conducted on July 17, November 17, December 4, December 19, 2000, and February 28, 2001, and presented in meeting minutes and other support documents. This Work Plan was prepared to be consistent with the requirements set forth in the Statement of Work and the Addendum to the Statement of Work prepared by USEPA (USEPA, 2000a and USEPA, 2000b).

1.1 WORK ASSIGNMENT OBJECTIVE

This Work Plan presents the approach that will be used to conduct a human health and ecological risk assessment for the site. Site-specific preliminary remediation goals (PRGs) for sediment will also be developed based on the results of the human health and ecological risk assessment.

Risk assessment activities will be performed in accordance with USEPA guidance documents (1989a-c; 1991a-c; 1992a-d; 1994; 1995; 1996a-b; 1997a-e; 1998a-b, 1999a). Human health risks will be evaluated for consumption of fish and other biota (e.g., turtles, frogs) present in the site waterways. Risks to onsite ecological receptors associated with constituents of concern identified at the site during previous investigation activities will also be evaluated.

1.2 WORK PLAN ORGANIZATION

This Draft Work Plan is divided into five sections: an introduction is provided in Section 1.0, a general site description and background information is presented in Section 2.0, data collection and analysis are discussed in Section 3.0, the methodology for conducting the human health risk assessment (HHRA) is presented in Section 4.0, and the methodology for conducting the baseline ecological risk assessment (BERA) is presented in Section 5.0. Other supporting information is provided in the appendices.

2.0 GENERAL SITE INFORMATION

2.1 SITE DESCRIPTION AND HISTORY

Two apartment complexes are located on the northern portion of the site. Centredale Manor, located at 2074 Smith Street (Route 44), is a multi-unit apartment complex for elderly adults. The Brook Village apartment complex is located at 2072 Smith Street. The site also consists of reaches of the Woonasquatucket River associated with Allendale Pond, Lymansville Pond, Manton Pond, and Dyerville Pond. The general limits of the site are defined by historical chemical manufacturing operations as well as by areas impacted by these operations. The site is bounded by Route 44 to the north, a former mill raceway and the eastern bank of the Woonasquatucket reach to the east, Dyerville Dam to the south, and the western bank of the Woonasquatucket reach to the west.

Prior to 1936, Centredale Worsted Mills, a woolens manufacturing plant, occupied the portion of the site located at 2072 and 2074 Smith Street. Circa 1940, Metro Atlantic Chemical Corporation began operations as a chemical manufacturer believed to manufacture hexachlorophene (of which hexachloroxanthene [HCX] is a by-product) and trichlorophenols. Operations at Metro Atlantic Chemical Corporation ceased during the 1960s or early 1970s. Between 1952 and 1969, New England Container Company operated a drum reconditioning facility on a portion of the property. Chemical residues were burned prior to drum reconditioning. In 1972, fire destroyed most property structures. Brook Village was constructed in 1977 and Centredale Manor was constructed in 1982.

Evidence of improper historical waste disposal was discovered during construction of the apartment complexes. Approximately 400 drums and 6,000 cubic yards of soil were removed from the site. Potential chemicals used onsite were identified based on drum labels including: caustics, halogenated solvents, polychlorinated biphenyls (PCBs), and inks. Evidence suggests that contaminants were buried, released directly to the ground, or released directly to the Woonasquatucket River. As a result, contaminants have migrated downstream and have impacted sediments in the Woonasquatucket River, Allendale Pond, Lymansville Pond, Manton Pond, Dyerville Pond, and some floodplain areas associated with these water bodies.

Elevated levels of dioxin were discovered in June 1996 in the Woonasquatucket River during a study conducted by USEPA Narragansett Laboratories and the Providence Urban Initiative Program. Subsequently, elevated concentrations of dioxin and PCBs were identified in sediment in the Woonasquatucket River and downstream impoundments in July 1998 during a study conducted by USEPA. Additional site investigations were performed between 1998 and 2000 to delineate the concentrations of dioxin in soil and sediment. Contaminants detected onsite

include: dioxin, PCBs, chlorinated and aromatic volatile organic carbons (VOCs), polycyclic aromatic hydrocarbons (PAHs), phthalates, and various metals. Further historical information is provided in the Expanded Site Investigation Report prepared by Roy F. Weston, March 1999.

A mill dam downstream of the apartment complexes (Allendale Dam) was partially breached in 1991, allowing the water in Allendale Pond to recede. As a result, most of the pond bottoms adjacent to residential properties along the eastern bank of Allendale Pond were exposed because they were no longer flooded. Since 1991, much of the Allendale Pond area has become vegetated. Allendale Dam will be reconstructed during the summer of 2001, thus restoring Allendale Pond.

A streamlined human health risk assessment was conducted at Allendale and Lymansville Ponds as part of an Engineering Evaluation/Cost Estimate (EE/CA) performed for the site in September 2000. Of the 36 exposure areas identified onsite, the target cancer risk was exceeded for dioxin at 20 areas and the target non-cancer risk was exceeded at nine areas. The primary constituents contributing to the risk included dioxins and furans, Aroclor 1254, arsenic, and PAHs. Dioxin was identified as the primary contributor to the unacceptable human health risk. Based on the results of the streamlined human health risk assessment, a cleanup goal of 1 part per billion (ppb) dioxin was established for selected soils that will be covered by less than one foot of water after restoration of the Allendale Dam. As mentioned above, reconstruction of Allendale Dam and any necessary soil removal will occur during the summer of 2001. USEPA plans to conduct an interim remedial action to remove selected soil and sediments in the Allendale and Lymansville reaches. Further information about the streamlined human health risk assessment is provided in the EE/CA report prepared by Tetra Tech NUS Inc. (2000a).

A streamlined ecological risk assessment was also conducted at Allendale and Lymansville Ponds as part of the EE/CA performed in September 2000. Receptors identified include invertebrate communities exposed to surface soil and sediment, piscivorous mammal and bird populations exposed to surface soil and sediment, insectivorous mammal and bird populations exposed to surface soil and sediment, and herbivorous mammal and bird populations exposed to surface soil and sediment. Many of the contaminants were found at concentrations exceeding ecotoxicity benchmarks; therefore, a baseline ecological risk assessment was recommended. The primary constituents contributing to the risk include dioxin and furans, PCBs, metals, PAHs, and HCX. Further information about the streamlined ecological risk assessment is provided in the EE/CA report prepared by Tetra Tech NUS Inc. (2000a).

In this document, the terms dioxins and furans refer to the chemical classes called polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The PCDDs include 75 individual compounds while the PCDFs include 135 different compounds. These individual compounds are referred to technically as congeners. One particular congener,

2,3,7,8-TCDD is considered the most toxic of these congeners. The term PCBs refers to a class of compounds that includes 209 different congeners. Of the 209 congeners, 12 are thought to have dioxin-like toxicity. These congeners are often referred to as dioxin-like PCB congeners.

2.2 CURRENT AND REASONABLY FORESEEABLE USES OF THE SITE

The northern portion of the site is occupied by the Brook Village and Centredale Manor apartment complexes (see "Source Area" on Figure 1). These parcels are currently occupied and covered by buildings, pavement, or landscaping. The remaining portions of the site consist of reaches and wetlands associated with the Woonasquatucket River and four manmade ponds. The river is not used as a source of drinking water. Per the Rhode Island Department of Environmental Management (RIDEM) Water Quality Regulations EVM 112-88.97-1 (June 23, 2000), the Woonasquatucket River (from Esmond Mill Drive in Smithfield to the CSO Outfall at Glenbridge Avenue in Providence) is classified as a Class B1 water body. Class B1 water bodies are:

> "designated for primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges."

The land-use for the northern portion of the site is expected to remain multi-family residential. Allendale Dam will be reconstructed in the summer of 2001 and the Allendale Pond area will be flooded to its original extent. Ultimately, the USEPA plans to restore the Woonasquatucket River and associated reaches and ponds to a fishable condition.

2.3 SUMMARY OF ENVIRONMENTAL CONDITIONS

Sampling activities conducted by USEPA and RIDEM revealed elevated polychlorinated dibenzo dioxins and furans (dioxins and furans) in soils and sediments as well as from fish taken from Woonasquatucket River. As mentioned above, other contaminants detected onsite include: PCBs, chlorinated and aromatic VOCs, PAHs, phthalates, and metals. The site was added to the National Priorities List on February 4, 2000. For the Woonasquatucket River, there is currently a fish consumption advisory in place that recommends that people not eat fish, eels, turtles, or plants from the river downstream of the Smithfield Treatment Plant.

Approximately 400 drums and 6,000 cubic yards of soil were removed from the property during construction of the apartment complexes. However, the exact locations of these remediation

activities are not known. Temporary caps were installed over heavily contaminated areas near residences. Interim soil caps were placed in the source area in July 2000.

Temporary fencing was erected around areas of contaminated surface soil in January 1999. The temporary fencing was replaced with chain-link fence between May and September 1999 to prevent access to contaminated areas.

Allendale Dam will be reconstructed during the summer of 2001, thus restoring Allendale Pond. For the purposes of the human health and ecological risk assessments, it will be assumed that the flooded condition that will exist after dam renovation is the baseline condition.

2.4 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) identifies potential source areas from which oil and/or hazardous materials (OHM) may have been released, the migration pathways through which OHM may have been transported and/or translocated to other environmental media, and where possible exposure may occur. The conceptual site model provides a framework for understanding sources of OHM, migration pathways, identification of potential receptors, and development of exposure profiles.

2.4.1 Source Area

As discussed in Section 2.1, releases of hazardous substances from former industrial operations have occurred at the site. The source area consists of two parcels located at 2072 and 2074 Smith Street (Lots 200 & 250) that cover approximately 9.7 acres (see Figure 1). Evidence suggests that operations at the chemical company and drum reconditioning facility resulted in waste disposal onto surface soil and beneath the ground surface. Wastes have also been released directly into the Woonasquatucket River, which runs along the western side of the source area (Tetra Tech NUS Inc., 2000a). Dioxin and furans have been detected in soils and sediments as well as in fish tissue collected in 1996 from the Woonasquatucket River. Other contaminants detected in site media include PCBs, VOCs, PAHs, HCX, phthalates, and metals. Figures 2a, 2b, and 2c present conceptual site models for each potential source of release: waste released directly onto the ground (Figure 2a), buried contaminants/debris and leaking underground storage tank (Figure 2b), and waste released directly into the Woonasquatucket River (Figure 2c).

2.4.2 Migration of OHM

Downstream sediments have been impacted through the transport and deposition of contaminants from the source area. Dioxins and furans have been detected in sediments at Allendale Pond and

Allendale Dam, which is approximately 2000 feet from the source area. With the partial breaching of Allendale Dam in 1991, contaminants continued to migrate downriver to Lymansville Pond. Evidence suggests that contaminants originating from the source area have migrated beyond Manton Dam down to Dyerville Pond (See Figure 1).

2.4.3 Potential Human Receptors

Consistent with USEPA objectives, only a single pathway will be evaluated for the HHRA: potential exposure to chemicals of potential concern (COPCs) via ingestion of fish and/or other biota. Contaminants that are present in surface water and aquatic sediments may have bioaccumulated in fish and other biota present in the Woonasquatucket River. These fish and other biota, including turtles and frogs, may be consumed by individuals that catch and/or consume biota from the river. Child, adolescent, and adult consumers may be exposed to COPCs via ingestion of fish and other biota. Both recreational and subsistence anglers/consumers will be evaluated in the HHRA.

2.4.4 Potential Ecological Receptors

Figure 3 presents a generalized food web for the site and identifies the principal receptor groups that may be at risk and the transport pathways between different media that may result in exposure. A conceptual site model for the Site is provided in Figure 4. Although the primary focus of the BERA will be on the effects of bioaccumulating compounds [particularly dioxins (including HCX), furans, and PCBs] on the ecological health of the Woonasquatucket River, several other classes of COPCs were also identified in the streamlined ecological risk assessment and these will also be evaluated. Of particular note, potential impacts to the macroinvertebrate community associated with the discharge of contaminated groundwater to the Woonasquatucket River in the vicinity of the Site will be a specific focus of the BERA.

In general, aquatic receptors (including invertebrates and both demersal and pelagic fish species) are exposed to COPCs in sediment and surface water via direct contact, direct ingestion, or by consuming prey items that have bioaccumulated COPCs. As discussed above, complete migration pathways, including discharge of site groundwater has resulted in contamination of both sediment and surface water media as well as biota. Semi-aquatic receptors (including mammals, birds, reptiles, and amphibians) may be exposed as a result of incidental ingestion of sediment, consumption of water, or ingestion of contaminated prey. Terrestrial invertebrates and wildlife that prey on these species may be exposed to COPCs in floodplain soil directly or by ingesting contaminated prey. Sections 5.1.2 and 5.2.1 describe the receptors and exposure pathways that will be evaluated in the BERA in greater detail.

3.0 DATA SUMMARY

The following section (3.1) provides descriptions of currently available analytical data for biota collected in the Woonasquatucket River, as well as for site sediments, surface water, and soil. These data were reviewed to determine the data gaps to be addressed during the upcoming sampling events. Data gaps are discussed in Section 3.2. The planned data collection activities are described in Section 3.3.

3.1 AVAILABLE DATA

This section provides a summary of data previously collected at the site. Biota tissue samples that have been collected are described in Section 3.1.1. Data collected for other environmental media are summarized in Sections 3.1.2 (sediment), 3.1.3 (surface water), and 3.1.4 (soil). A summary of available site data by medium and exposure area is provided in Table 3-1. The minimal biota tissue data are summarized in the following section.

3.1.1 Biota

The USEPA (1996) collected fish tissue data from two areas of the Woonasquatucket River from two locations: Valley Street and Smith Street. Sunfish muscle and offal tissues (three samples of each) were analyzed in the Valley Street sample and eel muscle and offal tissues (one sample of each) were analyzed in the Smith Street sample. At both sites, pesticides, PCBs, and various metals were detected in fish tissue. In 1999, Rhode Island Department of Health (RIDOH) conducted a fish tissue study at Centredale Manor and Esmond Dam. Tissues for four individual fish (two eel, one pumpkinseed, and one bluegill) were analyzed. Tissues were found to contain dioxins, furans, and PCBs. These limited historical tissue data will only be qualitatively evaluated in the human health and ecological risk assessments because laboratory reports are not available for validation, and analytical methods used differ from those that will be used during the upcoming tissue sampling and analysis program.

3.1.2 Sediment

The sediment matrix was divided into three submatrices: floodplain sediment/soil, bank sediment/soil, and aquatic sediment. Available data are summarized in detail below by submatrix. Further discussion of available sediment data is provided in the Final Technical Memorandum and the EE/CA (Tetra Tech NUS, 2000a,b). The information provided in this section reflects the database provided by Tetra Tech NUS in January 2001.

3.1.2.1 Floodplain Sediments

Floodplain sediment data are currently available for the Allendale and Lymansville reaches and in references areas of the site (Assapumpsett Brook and in the area of Greystone Mill Pond). Data are summarized below by reach:

- **Allendale Reach.** Twenty floodplain sediment samples were collected within the area. All samples were analyzed for pesticides/PCBs (not including any specific congeners) and total organic carbon (TOC). Nine of the 20 samples were analyzed for metals and semivolatile organic compounds (SVOCs). Sixteen of the 20 samples were analyzed for dioxins and furans. Acid volatile sulfides/simultaneously extracted metals (AVS/SEM) were also analyzed in these samples.

- **Lymansville Reach.** Ten floodplain sediment samples were collected within the area. All samples were analyzed for dioxins and furans, pesticides/PCBs (not including any specific congeners), and TOC. Five of the 10 samples were analyzed for SVOCs.

- **Reference Areas.** Eleven floodplain sediment samples were collected in these areas. Of the 11 samples, 10 samples were collected upgradient of the source area (in the area of Greystone Mill Pond). All 10 samples were analyzed for pesticides/PCBs (not including any specific congeners), dioxins and furans, and total organic carbon (TOC). Seven of the 10 were analyzed for SVOCs and two of the 10 were analyzed for metals and AVS/SEM.

  One floodplain sediment sample was collected in Assapumpsett Brook and was analyzed for metals, SVOCs, pesticides/PCBs (not including any specific congeners), dioxins and furans, total organic carbon (TOC), and AVS/SEM.

- **Manton and Dyerville Reaches.** No floodplain sediment samples were collected within these areas.

3.1.2.2 Bank Sediments

Bank sediment data are currently available for the Allendale and Lymansville reaches and in the upgradient reference area (i.e., Greystone Mill Pond). Data are summarized below by reach:

- **Allendale Reach.** Three bank sediment samples were collected within the area. All samples were analyzed for SVOCs, metals, pesticides/PCBs (not including any specific congeners), and dioxins and furans.

- **Lymansville Reach.** Fifteen bank sediment samples were collected within the vicinity of Greystone Mill Pond. All samples were analyzed for SVOCs, metals, and dioxins and furans. Thirteen of the 15 were analyzed for pesticides/PCBs (not including any specific congeners).

- **Reference Area.** Six bank sediment samples were collected in areas. All samples were collected from upgradient of the source area and analyzed for metals, SVOCs, pesticides/PCBs (not including any specific congeners), and dioxins and furans. No bank sediment samples were collected within the Assapumpsett Brook.

- **Manton and Dyerville Reaches.** No bank sediment samples were collected within the areas.

3.1.2.3 Aquatic Sediments

Aquatic sediment data are currently available for the Allendale, Lymansville, Manton, and Dyerville reaches and in reference areas of the site. These data were reviewed to determine whether *sufficient numbers of samples were collected and appropriate analyses were performed for the* purposes of calculating Biota Sediment Accumulation Factors (BSAFs). A discussion of samples and available analytical data by reach is presented below.

- **Allendale Reach.** Twenty-two aquatic sediment samples were collected within the area. All samples were analyzed for metals, SVOCs, pesticides/PCBs (not including any specific congeners), and TOC. Twenty-one of the 22 samples were analyzed for dioxins and furans, and AVS/SEM. Only one sample was analyzed for a PCB congener (congener 77 only).

- **Lymansville Reach.** Fourteen aquatic sediment samples were collected within the area. All samples were analyzed for metals, SVOCs, pesticides/PCBs (not including any specific congeners), dioxins and furans, AVS/SEM, and TOC.

- **Manton Reach.** Eleven aquatic sediment samples were collected within the area. Ten of the 11 samples were analyzed for SVOCs, pesticides/PCBs (not including any specific congeners), and dioxins and furans. Nine of the 11 samples were also analyzed for metals and TOC. Seven samples were analyzed for AVS/SEM. Only one sample was analyzed for PCB congeners (congeners 77, 126, 169).

- **Dyerville Reach.** Six aquatic sediment samples were collected within the area. All samples were analyzed for SVOCs, pesticides/PCBs (not including any specific congeners), dioxins and furans, and TOC. Four of the six samples were analyzed for metals, and three

of the six samples were analyzed for AVS/SEM. Only one sample was analyzed for a PCB congener (congener 77).

- Five aquatic samples were collected in reference areas. All samples were analyzed for SVOCs, metals, pesticide/PCBs, dioxin and furans, AVS/SEM, and TOC.

3.1.3 Surface Water

Surface water data are currently available for the Allendale and Lymansville reaches and in the upgradient reference area (the area of Greystone Mill Pond). Data are summarized below by reach. Further discussion of available surface water data is provided in the Final Technical Memorandum (Tetra Tech NUS, 2000b). The information provided in this section reflects the database provided by Tetra Tech NUS in January 2001.

- **Lymansville Reach.** Twenty-one surface water samples were collected within the area. All samples were analyzed for metals (total and dissolved), SVOCs, and pesticides/PCBs (not including any specific congeners). Twenty of the 21 samples were analyzed for dioxins and furans.

- **Allendale Reach.** Thirteen surface water samples were collected within the area. All samples were analyzed for metals (total and dissolved), SVOCs, pesticides/PCBs (not including any specific congeners), and dioxins and furans.

- **Greystone Mill Reach.** Three surface water samples were collected upgradient of the source area. All samples were analyzed for metals (total and dissolved), SVOCs, pesticides/PCBs (not including any specific congeners), and dioxins and furans.

No surface water samples were collected from the Manton or Dyerville Reaches or from Assapumpsett Brook.

3.1.4 Soil

A discussion of available soil samples and analytical data is presented in the following paragraphs. Detailed discussions of available soil data are provided in the Final Site Investigation Report (IT, 2000) and the Final Technical Memorandum (Tetra Tech NUS, 2000b). The information provided in this section reflects the database provided by Tetra Tech NUS in January 2001.

Soil data are currently available for areas in and downgradient of the source area down to Lymansville Dam. In 1998, five soil samples were collected from Centredale Manor property. One soil sample was collected from Brook Village. Analyses for these samples included SVOCs, pesticides/PCBs, dioxin, and HCX.

On January 15, 1999, 17 residential soil samples were collected from Centredale Manor, Brook Village, Lee Romano Little League Field, and the Boys & Girls Club. Samples were analyzed for dioxin only. Five additional residential surface soil samples were collected on January 27, 1999, from Lee Romano Little League Field and were analyzed for dioxin only.

During February 1999, approximately 221 soil samples were collected from the 0 – 0.5 ft interval at locations between Rte. 44 and Allendale Pond. Specifically, samples were collected from Centredale Manor and Brook Village properties and several residential properties located adjacent to the Centredale Raceway. Samples collected from the Centredale Manor and Brook Village properties were analyzed for 2,3,7,8-TCDD. Samples from the other residential properties were analyzed for all dioxins. These 221 samples consisted of bank and floodplain samples as well as source area samples and residential soil samples.

Between June and November 1999, soil and sediment sampling was conducted to determine removal response. A total of 581 samples were collected and analyzed for 2,3,7,8-TCDD. Samples were collected from previous EPA locations and from new locations. Samples were collected at 1-ft intervals to the water table. Of the 581 samples, 346 were analyzed for PCBs, and 80 were analyzed for VOCs, SVOCs, pesticides, herbicides, metals, and cyanide. These locations were randomly selected from most contaminated areas of the site (Tetra Tech NUS, 2000a). These samples consisted of bank and floodplain samples as well as source area samples and residential soil samples. Note that only surficial samples collected at the 0-1 foot interval (i.e., those most relevant for evaluating exposures to ecological receptors) are summarized in Table 3-1.

3.2 DATA NEEDS

This section provides a summary of the additional data needed to conduct the HHRA and BERA. Dalapon is identified as a COPC in site media. However, this parameter may ultimately be eliminated. A summary of the data needs is provided by exposure area and media is provided in Table 3-2.

3.2.1 Biota

To complete the site characterization and data collection of the fish consumption and ecological risk assessments, tissue samples of biota (such as fish, turtles, and frogs) must be collected in the

vicinity of the source area (i.e., the area occupied by Centredale Manor and Brook Village apartments; Lots 200 and 250), downgradient of the source area (Allendale, Lymansville, Manton, and Dyerville reaches), and in reference areas (Greystone Mill Pond and Assapumpsett Brook) in locations that are likely to be accessed by potential consumers and ecological receptors.

Information on anglers and their consumption patterns, including age of anglers, organisms consumed, fish consumption rates, and fish preparation methods is required. Harding ESE is currently collecting information concerning fish consumption for freshwater water bodies in Rhode Island, Connecticut, other New England states, and the U.S. Identification of species of biota consumed will be based on the most reliable local information. Any information obtained from the Rhode Island Department of Fish and Wildlife (RIDFW) or from other local sources (such as a thesis by a Brown University Student, Siemay Lee, who conducted a health risk assessment of the subsistence fishing Southeast Asian American population in Rhode Island) will be weighted heavily in the identification of biota species that will be collected, sampled, and evaluated. Harding ESE is also pursuing similar information from the RIDOH. Bob Vanderslice of that agency is the contact person concerning fish consumption advisories. In addition, information will be sought from Dr. Nancy Balcom of the Marine Sciences and Technology Center at the University of Connecticut. Dr. Balcom has conducted a study, "Quantification of Fish and Seafood Consumption Rates by Connecticut Citizens and Certain Subpopulations." This information will complement the Rhode Island information.

The identification of biota species consumed, consumption rates, and food preparation techniques is an important component of the risk assessment. Harding ESE would prefer to utilize information in following order of preference: the Woonasquatucket River; other Rhode Island water bodies; Connecticut water freshwater bodies; other New England surface water bodies; USEPA defaults for fish consumption.

RIDFW electroshocking survey from 1995 for the Woonasquatucket River identified the following species: bluegill and pumkinseed sunfish, white sucker, large mouth bass, tessellated darter, American eel, fall fish, chain pickerel, yellow bullhead, rainbow trout, and golden shiner.

Additional biota tissue data to support the BERA include crayfish, emerging aquatic insects, and earthworms. In addition, avian tissue samples will be collected to support an assessment of local swallow populations. These tissue collection activities are described in further detail in Sections 3.3.1.2 through 3.3.1.4.

3.2.2 Sediment

As discussed in Section 3.3.1.2, macroinvertebrates (e.g., crayfish) will be collected in each exposure area to evaluate aquatic food chain exposures in the BERA. The exposure areas are identified in Figure 1. Additional sediment samples will be collected in the areas of crayfish sample collection in order to estimate trophic transfer factors. Additional sediment samples will also be required to conduct the laboratory macroinvertebrate bioassays that will be conducted to evaluate the direct toxicity that sediment exposure represents to this receptor group.

3.2.3 Surface Water

Additional surface water samples will be required to support the aquatic macroinvertebrate community study that will be conducted as part of the BERA to evaluate the effects of groundwater discharge (in the vicinity of the Site). Additional surface water samples will also be collected upstream of the site to characterize the effects that nutrient stressors may be having on the macroinvertebrate community.

3.2.4 Floodplain Soil

As discussed in Section 3.3, floodplain invertebrates (earthworms) will be collected in each exposure area to evaluate vermivorous wildlife exposures and to estimate direct toxicity to soil fauna based on measured tissue burdens of bioaccumulating compounds. Additional floodplain soil samples need to be collected in the areas of earthworm collection in order to estimate trophic transfer factors for bioaccumulating compounds.

3.3 PLANNED DATA COLLECTION AND EVALUATION

The USEPA has identified additional data collection activities to support the HHRA and BERA based on previous site evaluations (specifically the screening human health and ecological risk evaluations [TetraTech NUS Inc., 2000a]) and on the known list of site-related COPCs in the Woonasquatucket River (e.g., dioxin-like compounds and other bioaccumulating compounds). For the purpose of the human health and ecological risk assessments, data needs include a variety of tissue collection activities (Section 3.3.1). Data collected specifically to support the BERA will also include population and community surveys (Section 3.3.2), toxicity tests (Section 3.3.3), habitat assessments (Section 3.3.4), sediment sampling (Section 3.3.5), surface water sampling (Section 3.3.6), and floodplain soil sampling (Section 3.3.7). A description of the ways the data will be used is provided in the following paragraphs.

Specific data collection activities will be focused on the exposure areas outlined in Table 3-1. Table 3-2 provides a summary of the types of data that will be obtained during the field investigation activities and the required analyses. Table 3-3 provides additional detail regarding biological data needs for the ecological risk assessment. Table 3-4 provides a summary of the biological data types that will be obtained during the field activities and the data quality goals associated with each task. Planned data collection activities are also discussed below.

3.3.1 Biota Tissue Sampling

Fish and other biota (e.g., frogs or turtles) tissue will be collected from the portion of the Woonasquatucket River that constitutes the site in order to evaluate *human health* risks associated with potential exposures to biota from the river consumed by the local populations. The biota tissue data will also be used to evaluate *ecological* risks associated with receptors that may ingest aquatic biota that have bioaccumulated or bioconcentrated site-related compounds in their tissue (Section 3.3.1.1). In addition, to evaluate direct exposure and/or ingestion risks to primary consumers, and food chain risks to secondary and tertiary consumers (e.g., piscivorous, insectivorous, and omnivorous wildlife), tissue samples of aquatic macroinvertebrates, floodplain invertebrates, and avifauna will also be collected as discussed in Sections 3.3.1.2, 3.3.1.3, and 3.3.1.4, respectively. Scientific collection permits will be obtained as required for these sampling activities.

The following paragraphs discuss the samples that need to be collected and the ways this information will be used in the evaluation of risks. The sampling procedures are discussed in Attachment B. Details regarding sample analyses protocol and requirements will provided in the Sampling and Analysis Plan (SAP) to be submitted to USEPA under separate cover.

3.3.1.1 Fish, Frogs, and Turtles – Human Health and Ecological Evaluation

Objectives. Biota samples will be collected from several exposure areas (Table 3-2) for evaluating human health risks associated with eating fish and other biota from the four reaches of the site (Allendale, Lymansville, Manton, and Dyerville Ponds). In addition, biota samples will be collected from the reference areas (Greystone Mill Pond and Assapumpsett Brook). These biota samples will also be used to evaluate potential risks to ecological receptors that ingest fish that have bioaccumulated or bioconcentrated site-related compounds in their tissue. As discussed in Section 5.2, the tissue data will be used directly in the BERA to estimate both direct effects to the sampled organisms (using critical body residues [CBR] data) and potential bioaccumulation risks to consumer species.

Three target biota species will be collected. Analytical results for these three species will be used for both the human health and ecological risk assessments. The objectives of the human health

and ecological risk assessments indicate that two of the target species would be the American eel and a turtle. The third species would be a finfish such as bass or sunfish. When the fish survey and collection activities are implemented, if the target species are not available a decision tree will be employed to modify the identified target species based on the actual availability of species in this reach of the river. If, prior to the implementation of fish survey/collection activities, information is obtained that turtles are not consumed in the area, another species will be selected based on that new information.

Table 3-2 provides a summary of the number of tissue samples to be collected by exposure/ reference area and the required analyses for those samples. As directed by USEPA, 10 samples of each of the three target biota species will be collected from the Allendale and Lymansville reaches. In the Manton and Dyerville reaches, 3 samples of one species from each reach will be collected. In each reference areas (Greystone Mill Pond and Assapumpsett Brook), 10 samples of each of the three target biota species will be collected. One of the fish species may be divided into the muscle (fillet) and offal, based on typical cooking preparation methods. A total of 166 biota tissue samples will be collected and evaluated in both the human health and ecological risk assessments. Biota tissue samples will be analyzed for SVOCs, PCBs/pesticides, metals, dioxins (including HCX) and furans, 12 WHO PCB congeners, percent lipids, and percent moisture.

Data on the size and age of organisms will also be gathered. Fish scales will be collected and individually labeled for subsequent aging. Fish species, gender (if possible), length, and weight will also be recorded.

Species Selection. The specific species collected for tissue analysis to support the biota consumption risk assessment and the baseline ecological risk assessment are based on human consumption patterns, availability of species in the collection areas, and the need to represent different trophic levels in the ecological risk assessment. In October 1996, the USEPA and RIDOH recommended a "catch and release" policy for fish caught in the Woonasquatucket River downstream of the Smithfield Treatment Plant. That advisory indicated that dioxin levels in eels and sunfish posed unacceptable cancer risks. On July 13, 1999, the USEPA issued a press release to remind the public of the fish consumption policy. In that press release, USEPA recommended that the public not eat fish, turtles, eels, or plants from the Woonasquatucket River. Therefore, eels, turtles, and sunfish have been identified as the biota target species for collection, sampling, and chemical analysis.

There will be a contingency plan in the SAP to be implemented in the field during the fish survey/collection activities. This contingency plan would be used to adjust one or more of the target species if (a) one or more of the target species are not present in sufficient quantity in the collection areas, or (b) newly obtained fish consumption information indicates that another species is a more important component of the local diet.

The contingency plan involves a decision tree that will guide the evaluation and finalization of target species for tissue collection and chemical analysis. The collection of biota for tissue analysis to support the fish consumption risk assessment will be implemented simultaneously with the fish population and community survey that will be completed as part of the BERA. This fish population and community survey is described in Section 3.3.2.3 of this workplan. The contingency plan will be included in the SAP.

For each of the target species, the HHRA and BERA may require different tissue sample type (fillet, whole body, offal). The identification of tissue sample type will be finalized once the presence and abundance of species is determined in the field. For the fish consumption risk assessment, the information obtained concerning preparation and cooking techniques for each target species will determine the appropriate tissue sample type.

The detailed technical approach to fish collection will be presented in the SAP to be completed in April 2001 which also specifies methods of analyses and detection limits. As needed, organisms within the same size and year classes will be composited to achieve sufficient volume for the analytical requirements, wrapped in aluminum foil and plastic freezer bags, and then shipped to the laboratory at 4°C for tissue analysis.

3.3.1.2 Aquatic Macroinvertebrates – Ecological Evaluation

Aquatic macroinvertebrates are directly exposed to COPCs in surface water and sediment. For many invertebrates, only the larval life-stages are aquatic; the adult forms of these macroinvertebrates leave the aquatic environment for reproductive purposes. Other macroinvertebrates (including crayfish, gastropods, and bivalves) live out their entire lives in the aquatic environment. These two groups of macroinvertebrates represent different exposures to different consumer species. For instance, fish and omnivorous mammals and birds that forage in stream channels may ingest the larval and nymphal stages of insects, whereas insectivorous birds and mammals are likely only be exposed to the adult life stages. Therefore, tissue sampling will be conducted to evaluate exposures to these different receptor groups.

Aquatic Macroinvertebrates. Macroinvertebrates will be collected in several exposure areas downgradient of the site (Table 3-3). Following study design verification to determine the presence and relative abundance of macroinvertebrates within the study reaches, it is anticipated that crayfish will be selected as the target taxonomic group. A total of 11 crayfish samples will be collected from Allendale Pond (3), Lymansville Pond (4), Greystone Mill Pond (3) and Assapumpsett Brook (1) using a combination of dipnets and baited traps. Traps will be set out and checked daily until the necessary tissue volume has been collected for a sample. Samples will be washed, composited, packaged, and shipped on dry ice to an analytical laboratory for

chemical analysis. As presented in Table 3-2, crayfish tissue will be analyzed for pesticides/PCBs, Dalapon, metals (including methylmercury), dioxins and furans (including HCX), 12 WHO PCB congeners, percent lipids, and percent moisture.

Emerging Adult Insects. Five box-type floating emergence traps will be deployed in each of the following areas: Allendale Pond, Lymansville Pond, and Greystone Mill Pond. The traps will be used to collect tissue data and to characterize the emerging insect community structure. Sampling will occur immediately following the tree swallow population study to avoid depressing available forage during this critical forage period. Each trap will consist of a 1-meter square Plexiglas structure supporting a conical nylon net. The traps will be inserted in closed foam strips to provide flotation and attached leads allow the traps to be anchored in place (Southwood, 1978). Emerging insects will be sampled every two days using an insect vac and the samples will be chilled to facilitate taxonomic classification, enumeration (see Section 3.3.2.1) and preparation of composited tissue samples. These data will be used to supplement data on the macroinvertebrate community productivity as well as to provide tissue analytical data to assess direct effects to macroinvertebrates and to assess contaminant dose exposures to insectivorous birds (e.g., tree swallows) and mammals (e.g., little brown bat). The insect tissue samples will be analyzed for pesticides/PCBs, Dalapon, metals (including methylmercury), dioxins and furans (including HCX), 12 WHO PCB congeners, percent lipids, and percent moisture (Table 3-2).

3.3.1.3 Floodplain Invertebrates – Ecological Evaluation

Floodplain invertebrates are directly exposed to COPCs in floodplain soil. These invertebrates provide a forage base for higher trophic level predators; therefore, tissue sampling will be completed to evaluate potential food chain risks to semi-aquatic wildlife receptors that forage in floodplain environments. Earthworms, which typically inhabit floodplain soil, will be the focus of this assessment. The abundance of the soil fauna associated with the Woonasquatucket River floodplain soils will be assessed during the study design field verification (Step 5, USEPA, 1997d).

If sufficient earthworm biomass is available in floodplain soil within each exposure area, earthworms will be collected at a range of locations where historical data indicate that a concentration range of bioaccumulating compounds are located. As indicated in Table 3-2, a total of 11 earthworm samples will be collected from Allendale Pond (3), Lymansville Pond (4), Greystone Mill Pond (3) and Assapumpsett Brook (1). Samples will be washed, composited, packaged, and shipped on dry ice to an analytical laboratory for chemical analysis. Earthworm tissue will be analyzed for pesticides/PCBs, Dalapon, metals (including methylmercury), dioxins and furans (including HCX), 12 WHO PCB congeners, percent lipids, and percent moisture.

A composite soil sample will also be collected at each of the earthworm tissue sampling locations and analyzed for the same chemical parameters listed for the earthworm tissue (see Section 3.3.7) SVOCs (to assist in the evaluation of community level effects [see Section 3.3.2.2]), TOC, and grain size.

3.3.1.4 Avifauna – Ecological Evaluation

Insectivorous birds (e.g., swallows) prey on flying insects that have been exposed to COPCs in surface water and sediment during their larval aquatic life stages. In addition to the emergence test discussed in Section 3.3.1.2, tree swallow nest box monitoring and sample collection activities will be implemented to determine the levels of bioaccumulating compounds in eggs and nestling tissue. In addition, composite stomach content samples will be collected from the Allendale Pond, Lymansville Pond, and Greystone Mill Pond study areas.

These data will provide a direct measure of the body burdens of bioaccumulating compounds, which will then be used in the BERA to evaluate the bioaccumulation hazard posed by food chain exposures to these receptors. Five swallow egg, nestling, and liver samples, as well as three stomach content samples, will be collected from each of the sampling areas (Table 3-3). All samples will be analyzed for PCBs/pesticides, Dalapon, dioxins and furans (including HCX), the 12 WHO PCB congeners, percent lipid, and percent moisture. The liver samples will also be analyzed for metals (including methylmercury). The details of the tree swallow nest box monitoring and tissue sampling will be presented in the SAP.

3.3.2 Population and Community Surveys

Several surveys will be completed to evaluate the impacts that site-related COPCs may have on invertebrates, fish, and avian populations and/or communities. Population- and community-level studies are focused on evaluating relative population abundance, species richness, and/or reproductive success. The following sections describe the surveys that will be completed for various ecological receptor groups.

3.3.2.1 Aquatic Macroinvertebrates

The aquatic macroinvertebrate communities in lotic (i.e., riverine) environments downstream of the Site will be surveyed following the multi-habitat approach outlined in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition* (Barbour et al., 1999). These data will be used to determine the level of macroinvertebrate community impairment relative to the upstream and reference sampling locations (i.e., below Greystone Mill Pond and Assapumpsett Pond, respectively). The specific focus of this study is to evaluate the potential effects of discharging groundwater in the reach adjacent to the Site and to assess the potential

role that surface water COPCs and nutrients may have on this community. The Smithfield Waste Water Treatment Plant (WWTP) located between Greystone Mill Pond and the Site is a known source of nutrients to the Woonasquatucket River (Louis Berger Group, Inc., 2000). Macroinvertebrate sampling areas are targeted to allow discrimination of the effects of the WWTP and groundwater discharge from the Site. Three sampling areas are situated in the reach below Greystone Mill Pond (above, adjacent to, and downstream of the WWTP). Similarly three locations will be sampled in the lotic reach from Route 44 to the lotic/lentic transition area above Allendale Pond. Two samples will be collected in the riverine section of the river below Allendale Pond to assess community recovery and two locations in Assapumpsett Brook to characterize background conditions.

Surface water samples will be collected at each of the 10 macroinvertebrate community sampling areas and will be used in conjunction with existing sediment data to evaluate the nature of potential stressors to the macroinvertebrate community (see Section 3.3.6). In addition, groundwater analytical data collected as part of the ongoing Groundwater Remedial Investigation and existing vapor diffusion sampler (VDS) data will be evaluated.

A D-frame dip net will be used to sample invertebrates from each ayailable microhabitat encountered (e.g., cobble, snags, banks, submerged macrophytes, and fine sediment). Macroinvertebrates will be placed in jars and preserved with 75 percent ethyl alcohol, and shipped to a biological laboratory for taxonomic identification, enumeration, and calculation of metrics (including species richness, relative abundance, degree of pollution tolerance, and functional feeding categories [Plafkin et al., 1989]). Biological Condition Scores will be calculated for each study area and compared to the upstream and reference locations to assess the degree of impairment. Attachment B provides a summary of the proposed macroinvertebrate survey.

Emerging Adult Insects. The abundance and species richness of the insect fauna collected in the emergence traps deployed in Allendale Pond, Lymansville Pond, and Greystone Mill Pond (as described in Section 3.3.1.2) will be determined to assess potential impacts of sediment contamination on the macroinvertebrate community. Emerging insects will be sampled following the completion of the swallow study (Section 3.3.1.4) to avoid affecting any depression of available forage to nestling swallows. Sample results will be tabulated and total abundance, abundance of dominant taxa, and species richness estimates will be plotted. The null hypothesis that there are no statistical differences in these metrics between the two study areas and the reference area will be tested.

3.3.2.2 Floodplain Soil Fauna

The potential effects of certain COPCs detected in floodplain soils (including SVOCs, pesticides, and metals) on the soil faunal community will be assessed. Three samples will be collected from floodplain sediments/soils from Greystone Mill Pond and Allendale Pond, four locations from Lymansville Pond floodplains, and one sample from Assapumpsett Pond. At each of the 11 biological stations, a standard size plot (1 meter by 1 meter by 0.5 meter) will be established to demarcate an area for habitat characterization and earthworm collection. The soil infauna in 5 replicate subsamples from each sample plot will be categorized and enumerated and all earthworms within the plot then collected for subsequent tissue sampling along with a composited soil sample for chemical analysis (see Section 3.3.7). The substrate and overlying vegetation will be characterized, and macroscopic soil organisms will be collected by soil sieving (Southwood, 1978). A similar effort will be conducted in a comparable reference area of suitable habitat. The following information will be documented:

- relative abundance of other macroscopic life (e.g., larvae or adult forms of invertebrates);
- earthworms weight and total number;
- evidence of cocoons;
- topography of sample area;
- dominant vegetation in area; and,
- soil classification.

Results will be compared to identify potential differences among sampling locations (relative to reference areas) that may be related to contaminant exposure. Biomass and total earthworm abundance data will be compared within each soil classification category and examined for correlations with patterns of contaminant concentrations. Depending upon the number of identified soil categories, the earthworm data may be statistically evaluated (e.g., Kruskall-Wallace) although the number of sample locations will limit statistical power.

3.3.2.3 Fish

A fish population and community survey will be completed in lotic and lentic (i.e., pond) environments downstream of the Site following the framework of the Index of Biotic Integrity (IBI), as outlined in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition* (Barbour et al., 1999). The survey will be conducted concurrently with fish tissue sampling activities and the results will inform the selection of specific species for tissue analysis (see Section 3.3.1.1). Fish will be collected using the techniques outlined in Attachment A, including electroshocking and nets, and placed in live wells prior to collection population data and possible preparation for tissue analysis. Animals that are not selected for tissue analysis will be returned to the approximate location of capture. Species will be identified, enumerated,

length-weight relationships and condition indices will be measured, and any observations of gross morphological abnormalities (e.g., lesions, deformities) and the presence of ectoparasites will be noted. Fish scales will be collected to provide age data to evaluate the demographic structure of the fish populations in the study area relative to the reference areas. Specific details of the fish community structure assessment will be provided in the SAP.

In addition, an ichthyoplankton survey will be completed to obtain community measures of species richness and relative abundance. Ichthyoplankton surveys will be conducted in Allendale Pond, Lymansville Pond, Greystone Mill Pond, and Assapumpsett Pond (Table 3-3). A detailed description of the sampling procedures to be employed will be provided in the SAP. Due to variability in site conditions (e.g., shallow water depth, presence of snags), selection of specific sampling methodologies within each reach will be determined in the field.

3.3.2.4 Insectivorous Birds

Three local populations of the tree swallow (*Tachycineta bicolor*) associated with Allendale Pond, Lymansville Pond, and Greystone Mill Pond will be evaluated to characterize the magnitude of potential exposures and effects of dioxin-like compounds that have entered the aquatic food chain (Figure 3). Approximately 30 nest boxes will be established in each exposure area and the boxes monitored until nestlings are 12 days old. Sensitive reproductive effects, including productivity/nest box, hatchling success, survival rates, nestling weight, and the presence of gross abnormalities in nestlings will be measured. The significance of the reproductive data collected during this study will be determined by comparing results obtained from the Allendale Pond and Lymansville Pond populations to the Greystone Mill Pond results.

Tissue samples of swallow eggs and nestlings, including whole body, liver, and stomach contents will also be collected as described in Section 3.3.1.4. Details of the swallow nest box study will be provide in the SAP.

3.3.3 Toxicity Testing

Toxicity testing will be completed to determine the direct impacts that site-related COPCs have on aquatic receptor populations in exposure areas downgradient of the Site. Assuming that significant toxicological responses are identified, a second objective will be to identify toxicological thresholds for potential contaminant effectors to aid in identifying PRGs. The proposed toxicity tests are described in the following sections.

3.3.3.1 Aquatic Macroinvertebrates

The midge, *Chironomus tentans*, and the amphipod, *Hyalella azteca* have been selected as representative infaunal macroinvertebrate receptors for whole sediment toxicity tests. The chronic toxicity tests selected for these receptors include a life cycle and 42-day duration test for *Chironomus tentans* and *Hyalella azteca*, respectively. Endpoints measured will include survival, growth, and reproduction. Negative control and reference treatments (i.e., Greystone Mill Pond and Assapumpsett Pond) will be included. A total of 8 sediment samples will be collected to conduct the laboratory bioassays: 3 samples from both Allendale and Lymansville Ponds and a sample from the Greystone Mill Pond and Assapumpsett Pond (Table 3-3). Sample locations will be identified in the SAP and will be selected to provide a range of COPC exposures of the most likely stressors. This will allow evaluation of patterns of contaminant concentration and observed biological response.

Sediment for the laboratory bioassays will be collected using a gravity corer, Ekman and/or Ponar dredge, or stainless steel sampling spoons depending on substrate characteristics and water depth. Reference sediment (i.e., Greystone Mill Pond and Assapumpsett Pond) with similar physical characteristics (i.e., grain size, total organic carbon) will also be collected. Sediment samples will be kept on ice (2-4°C) until test commencement. The sediment will be sieved to remove potential predators, large organic matter and stones. In addition to the reference treatments, a negative control, consisting of 10 percent sphagnum moss, 20 percent kaolin clay, and 70 percent silica sand will also be employed. A subsample of each sediment sample will be collected following homogenization and submitted to an analytical laboratory for chemical analysis (see Section 3.3.5).

The life-cycle toxicity test for *C. tentans* will be conducted following the procedures described in the USEPA protocol: Test Method 100.5, *Life-Cycle Test for Measuring the Effects of Sediment-Associated Contaminants on Chironomus tentans*. This test measures the effects of sediment-associated contaminants on survival, growth, and reproduction (USEPA, 2000c). The test starts with newly hatched larvae (less than 24-hours old). Endpoints measured in this test will include survival (Day 20 and end of test [Day 50 to 65]) and growth (Day 20). Emergence and reproduction will be measured from Day 23 to the end of the test. In addition, the time to death (adults) is also monitored, post Day 20. Replicates will be monitored daily for egg cases, which will be removed and incubated for 6 days to determine hatching success. The test is terminated when no additional emergence has been recorded for 7 consecutive days. The test initially requires 12 replicates, set-up on Day 1, of which four will be dedicated to the 20 day growth and survival endpoints and eight dedicated to the evaluation of emergence and reproduction endpoints. On Day 10, four additional replicates will be established to provide additional organisms for the reproduction phase of the toxicity test. Each treatment in the midge life-cycle test will consist of 16 replicate 300-ml lipless beakers containing 100 ml of sediment and 175 ml

of overlying water. Midges will be fed daily (1.5 ml of a 4-g/l Tetrafin® solution daily) and the overlying water will be changed twice daily.

The 42-day toxicity test for *H. azteca* will be conducted following the procedures described in the USEPA test protocol: Test Method 100.4, *Hyalella azteca 42-d Test for Measuring the Effects of Sediment-associated Contaminants on Survival, Growth, and Reproduction*, (USEPA, 2000c). The test starts with 10, 7- to 8-day old amphipods. Endpoints measured in this test include survival (Day 28, 35, and 42), growth (dry weight measured on Day 28 and 42), and reproduction (number of young per female produced from Day 28 to 42) (USEPA, 2000). Reproductive endpoints will be measured by isolating amphipods from sediment and placing them in water-only chambers on Day 28. Subsequently broods of young will be counted on Day 35 and 42, allowing quantitative measure of reproduction. The specified test design involves a total of 12 replicates for each treatment: 4 replicates for the 28-day growth and survival endpoint, and 8 replicates for the measurement of survival and reproduction on Day 35 and for measurement of growth, survival, and reproduction on Day 42. Each treatment in the 42-day amphipod test will consist of 12 replicate 300-ml lipless beakers containing 100 ml of sediment and 175 ml of overlying water. The amphipods in each replicate will be fed daily (1.0 ml of Yeast, Cerophyl®, and Trout chow solution) and the overlying water will be changed twice daily.

Following 28-days of exposure, amphipods from 4 of the 12 replicates per treatment will be removed and surviving individuals will be counted and preserved for growth measurements. Growth will be quantified as the average dry weight of individual amphipods in each replicate (e.g., dried at 60°C for 24 hrs). The remaining 8 replicates will be used for reproduction measurements. The amphipods will be removed from the sediment exposure chambers (i.e., 300-ml beakers) and placed in water-only beakers, which will then be exposed for an additional 14 days. On Day 35, the number of surviving adults and offspring will be counted and the offspring removed. On Day 42, the surviving adults and offspring will be counted; surviving adults will be preserved and the adult males counted. The counts will be used to calculate the number of young produced per female per replicate from Day 28 to Day 42. Statistically significant treatment effects will be determined by comparing results to both reference results; the negative control will be used to evaluate test validity.

3.3.3.2 Fish

To evaluate the effects of dioxin-like compounds in Allendale Pond on early life stages of fish, a study will be completed in which fertilized eggs are exposed to a dilution series of a chemical mixture synthesized to replicate the COPC contents of whole fish collected from Allendale Pond. Range finding and reference toxicant tests will also be performed. The experimental design calls for analyzing COPCs from homogenized whole fish using chromatography for organics.

This test is anticipated to represent a maximum exposure to eggs via the maternal pathway as the COPCS from all parts of the body will be represented in the analysis that is the basis for synthesis of the exposure solution.

The study will include a literature review of ELS exposures and chemical characteristics, which will help to determine the appropriate species for the test organism, the constituents of the chemical mixture, exposure parameters, and proper endpoints. Preliminary tests will ascertain the optimal adaptations of husbandry techniques and identify appropriate exposure dilutions.

Based on information on declining populations of the bullhead in the Woonasquatucket River, it is tentatively proposed that a close relative of the bullhead, the channel catfish, be used in the ELS study. Study endpoints may include:

- Time to hatch;
- Survival to hatch;
- Body burden of the fertilized eggs;
- Survival of post-hatch fish;
- Abnormalities in behavior and appearance; and
- Growth (mm length and grams weight).

It is proposed that resident fish species for this test be collected from the vicinity of an identified dioxin-like compound hot spot from Allendale Pond. Fertilized eggs for the exposure will be collected from catfish in a hatchery pond. The test will include organic chemical analysis by chromatography of fish tissue, the synthetic chemical mixture, and fish eggs. If the synthesis of the chemical mixture proves impractical or prevents the study schedule from being met, a more limited study of exposure to COPCs derived from sediments or fish of Allendale Pond may serve as an alternative approach; further discussions with USEPA would be necessary in this case.

The definitive tests will result in the determination of ED50 (dose at which the measured effect occurred in 50 percent of the test population), LOED, and NOED. Endpoints such as abnormalities in behavior and appearance, and effects on growth and survival, will be discussed with respect to the known effects of COPCs identified in the fish tissue. These estimated doses will be used to assess risks and to develop PRGs, if warranted. The detailed study design will be presented in the SAP.

3.3.4 Habitat Assessment and Wildlife Surveys

In conjunction with the macroinvertebrate community assessment described above, the physical in-stream and bank habitat will be characterized in the same portions of Woonasquatucket River

downgradient of the Centredale Manor Site consistent with the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition* (Barbour et al., 1999). Information concerning riverbed substrate, flow rates, water depth, river width, presence and types of macrophytes, local land use, and other features (e.g., riffle/run habitat) will be obtained during a complete transverse of the study area. The adjacent floodplain and upland plant communities will be described floristically and photodocumented. Incidental observations of foraging or breeding piscivorous, insectivorous, and omnivorous wildlife will be recorded as noted.

3.3.5 Sediment

Table 3-2 provides a summary of sediment samples that will be collected to support the ecological risk assessment. For the purposes of evaluating crayfish uptake of bioaccumulating compounds from sediment (Section 3.3.1.2), 11 sediment samples will be collected as follows: 3 sediment samples from the Allendale reach; 4 sediment samples from the Lymansville reach; 3 samples from Greystone Mill Pond; and 1 sample from Assapumpsett Brook. These sediment samples will be analyzed for PCBs/pesticides, Dalapon, metals (including methylmercury), dioxins and furans (with HCX), 12 WHO PCB congeners, TOC, AVS/SEM, grain size, and percent moisture.

For the purposes of conducting the laboratory invertebrate bioassay (Section 3.3.3.1), 8 samples will be collected as follows: 3 sediment samples each from the Allendale and Lymansville reaches; 1 sample from Greystone Mill Pond; and 1 sample from Assapumpsett Brook. These sediment samples will be analyzed for SVOCs, PCBs/pesticides, Dalapon, metals (including methylmercury), TOC, AVS/SEM, grain size, and percent moisture (Table 3-2).

3.3.6 Surface Water

Table 3-2 provides a summary of the surface water samples that will be collected to support the macroinvertebrate community evaluation described in Section 3.3.1.2. A total of 10 surface water samples will be collected from riverine portions of the study area: 3 surface water samples will be collected from Allendale reach adjacent to and immediately downstream of the Site, 3 samples will be collected downstream of Greystone Mill Pond (upstream, adjacent to, and downstream of the Smithfield WWTP), 2 samples collected below the Allendale Pond dam, and 2 samples from Assapumpsett Brook downstream of the pond. Samples will be analyzed for VOCs, SVOCs, PCBs/pesticides, Dalapon, metals, hardness, and nutrients (including various forms of nitrogen and phosphorous). Dioxins, furans, and coplanar PCB analysis is not required as macroinvertebrates are relatively insensitive to these COPCs (USEPA, 1993; West et al., 1997).

3.3.7 Floodplain Soil

Table 3-2 provides a summary of the floodplain soil samples that will be collected to support the floodplain soil fauna community study (Section 3.3.2.2) and to estimate biological uptake into earthworm tissue (Section 3.3.2.2). Eleven samples will be collected as follows: 3 soil samples from the Allendale reach; 4 soil samples from the Lymansville reach; 3 samples from Greystone Mill Pond; and 1 sample from Assapumpsett Brook. These floodplain soil samples will be analyzed for SVOCs, PCBs/pesticides, Dalapon, metals (including methylmercury), dioxins and furans (with HCX), 12 WHO PCB congeners, TOC, grain size, and percent moisture.

4.0 BASELINE HUMAN HEALTH RISK EVALUATION

After evaluation of the field investigation information and establishment of the database for the site, Harding ESE will conduct a baseline HHRA for the consumption of fish and other biota (e.g., turtles and frogs) and will prepare the necessary risk assessment documents. The objective of the baseline biota consumption risk assessment will be to characterize, and quantify where appropriate, the current and potential baseline human health risks that would prevail if no further remedial action is taken.

The HHRA will provide calculations and a discussion of potential risks from consuming edible portions of fish and other biota from the portion of the Woonasquatucket River in North Providence, Rhode Island that constitutes the site. For the Woonasquatucket River, there is currently a fish consumption advisory in place for all fish species prohibiting consumption under current conditions. In 1999, USEPA recommended in a press release that the public not eat fish, eels, turtles, or plants from the river downstream of the Smithfield Treatment Plant. Therefore, current exposures are assumed to be minimal. However, potential future exposure to fish and other biota (including high lipid content biota such as eels) may occur in the future, assuming that the river will be restored to an unrestricted "fishable" river.

For human health, only the biota consumption pathway will be evaluated. A streamlined human health risk assessment was conducted as part of an EE/CA performed for the site in September 2000. That evaluation was performed to identify the risk to humans from soil and sediment at the site to help support removal actions. It is expected that additional pathways (associated with surface water, groundwater, air, etc.) will be addressed in future reports.

The primary objectives associated with this risk evaluation will be:

- to determine contaminant levels in consumed biota in order to determine exposure levels for consumers;
- to calculate potential human health risks associated with biota consumption from the portion of the river within the study area;
- to assess whether exposures and associated risk levels for biota consumption are above Superfund thresholds that initiate risk management activities; and
- to develop PRGs for sediment.

The HHRA activities will be conducted in accordance with Section 6.2 of the Statement of Work and the Addendum to the Statement of Work for the baseline biota consumption risk assessment (USEPA, 2000a and USEPA, 2000b).

The HHRA will include the following tasks (as described in the specified sections):

- Hazard identification (Section 4.2);
- Exposure assessment for current and future land uses (Section 4.3);
- Toxicity assessment (Section 4.4);
- Risk characterization (Section 4.5); and
- Limitations and uncertainties (Section 4.6).

Section 4.1 discusses submission of the final HHRA report and also describes the portions of the HHRA to be submitted to reviewers as interim deliverables.

4.1 INTERIM DELIVERABLES

The final product will be the final baseline biota consumption risk assessment report comprised of a completed baseline human health risk assessment focusing on the consumption of fish and other biota (e.g., turtles, frogs). Prior to submission of the final report, portions of the draft baseline biota consumption risk assessment in the form of interim deliverables (as described below) will be submitted. These interim deliverables shall be reviewed and accepted by the USEPA Remedial Project Manager prior to proceeding with the next interim deliverable. Once all interim deliverables are accepted, the draft biota consumption risk assessment report will be submitted. This will include the interim deliverables as well as the additional information required for the report.

The interim deliverables will consist of the following:

First Interim Deliverable

- Hazard Identification I (including discussion of selection of chemicals of concern)
- Exposure Assessment I (including assumed consumption patterns based on the literature and exposure data from similar assessments performed in the northeast)

Second Interim Deliverable

- Revised Hazard Identification
- Revised Exposure Pathways And Parameters
- Development Of Exposure Point Concentrations
- Toxicity Assessment

Third Interim Deliverable

- Draft Baseline Biota Consumption Risk Assessment

The Final Baseline Biota Consumption Risk Assessment will be submitted after approval of all interim deliverables.

Discussions of specific risk assessment components are provided in the following subsections.

4.2 HAZARD IDENTIFICATION

The objective of this component is to present an orderly compilation of the available sampling data on the hazardous substances present at the site, to identify data sets suitable for use in a quantitative risk evaluation, and to identify contaminants of concern upon which the quantitative assessment of risk will be based. Summaries of the sampling data will be generated using Risk Assessment Guidance for Superfund (RAGS) Part D standard Table 2s, for each constituent detected in biota. Table 2s include the minimum and maximum concentrations (including locations of the latter), minimum and maximum data qualifiers, units, frequency of detection, range of detection limits, concentration used for screening, screening toxicity value, potential regulatory criteria (i.e., FDA levels, state standards), whether a contaminant is chosen as a COPC, and the rationale for that choice. When choosing COPCs, USEPA guidance will be followed.

All pollutants detected during sampling efforts, not just site-related pollutants or those that bioaccumulate, will be considered in the selection of COPCs for the human health evaluation. This will likely result in a total estimate of risk to the consumer associated with the consumption of fish and other biota caught from the river. However, persistent, bioaccumulating chemicals (e.g., PCBs, dioxin and dioxin-like compounds, and various metals) detected in biota tissue will be the focus of the HHRA. Per USEPA, Region I guidance, background data shall not be considered when choosing COPCs.

Chemicals that are infrequently detected may be artifacts in the data due to sampling, analytical, or other problems, and may not be related to site operations or disposal practices. These chemicals will be identified and eliminated from the risk assessment. In addition, chemicals that are essential human nutrients (i.e., iron, magnesium, calcium, potassium, and sodium) will not be considered in the quantitative risk assessment.

4.3 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of exposures to COPCs at or migrating from the site. The exposure assessment will be conducted to characterize the populations of receptors potentially exposed via consumption of biota from the Woonasquatucket River, the mechanisms by which receptors may be exposed, and the intake, or

dose, of COPCs that receptors may receive through the identified exposure pathways. The exposure assessment will include the following components:

- Characterization of the exposure setting (including current and future land use);
- Identification of exposure pathways (including receptor identification and exposure points);
- Identification of exposure point concentrations;
- Quantification of exposures; and
- A summary of exposures by receptor and exposure point.

As part of this section, RAGS Part D Table 1 (the overall conceptual site model) will be submitted. Present and future potential exposures to site contaminants will include the ingestion of fish (and other biota) by potential human receptors and include an evaluation of sensitive receptors. In addition, the biota populations consumed by the local population will also be identified. Narrative descriptions and summary tables of exposure scenarios will be provided in this section. The exposure scenarios for current and potential scenarios shall be summarized in RAGS Part D Table 4s.

4.3.1 Characterization of Exposure Setting

The physical characteristics of the site and the nature of the surrounding populations will be evaluated to provide a basis for assessing potential exposures. The HHRA will summarize important site characteristics that may influence human contact with site contaminants including surface conditions and degree of vegetative cover (as they pertain to the accessibility of potential recreational areas for angling) and climate.

4.3.2 Identification of Exposure Pathways, Potential Receptors, and Exposure Points

Exposure Pathways

This step involves the identification of all relevant exposure pathways through which specific populations may be exposed (current and future) to contaminants at the site. An exposure pathway consists of four necessary elements: a source or mechanism of chemical release, a transport or retention medium, a point of human contact, and a route of exposure at the point of contact (USEPA, 1989a).

In accordance with USEPA goals and objectives, the baseline HHRA to be performed for this site will include an evaluation of a single exposure pathway: current and potential future ingestion of biota by anglers or other consumers from the reach of the Woonasquatucket River

that constitutes the site. The current level of consumption of fish from the Woonasquatucket River is assumed to be minimal. Currently, there is a fish consumption advisory issued by the State of Rhode Island to prevent significant exposure to biota from the river in the short-term. No other routes will be considered.

Potential Receptors

Potential future exposure to fish and other biota (including high lipid content biota such as eels, frogs, and turtles) may occur, assuming that the river will be restored to an unrestricted "fishable" river. Anglers who ingest fish taken from the river may be exposed to COPCs through biota that have bioaccumulated chemicals from the river system. The following receptor exposure scenarios will be evaluated for ingestion of fish and other biota tissue:

- Recreational angler (young child, older child, and adult): Possible exposures to COPCs via ingestion of fish and other biota.

- Subsistence angler/consumer (young child, older child, and adult): Possible exposures to COPCs via ingestion of fish and other biota.

The central tendency (CT) and reasonable maximum exposure (RME) scenarios will be characterized by coupling the contaminant concentrations with conservative exposure parameters developed for each exposure scenario. The CT and RME scenarios will be summarized in RAGS Part D Tables 7, 8, 9 and 10, and results will be described in the text. Exposure parameters will be obtained from USEPA guidance (USEPA, 1997a) and other USEPA-approved sources.

Exposure Points

Multiple exposure points will be identified. Exposure points will be areas defined by impoundments. There are four separate exposure points that include Allendale reach, Lymansville reach, Manton reach, and Dyerville reach. Two Reference Areas (Assapumpsett Brook and Greystone Mill Pond) have also been identified as exposure points for the fish consumption assessment. The risk assessment calculations and conclusions for the latter two exposure points will be documented and presented in a document that will follow the final Baseline Risk Assessment (Derivation of Preliminary Goals and Discussion of Risks at Background Conditions).

4.3.3 Exposure Point Concentrations

A single concentration will be selected as representative of the actual concentration for each COPC in a given medium for a given exposure point. This value, called the exposure point

concentration (EPC), will be used in the estimates of health risks at the site. An EPC is selected for every COPC identified in the screening process described earlier.

As directed by USEPA, the EPC for each exposure point will be the 95 percent Upper Confidence Limit (UCL) on the mean fish tissue concentration at the exposure point. If the 95 percent UCL is greater than the maximum detected concentration, the maximum concentration will be used as the exposure point concentration (USEPA, 1994). For this assessment, it will be presumed that contaminated concentrations in biota tissue are log-normally distributed (USEPA, 1992b). The following equation will be used to calculate the UCL on the arithmetic mean (USEPA, 1992b):

$$UCL = e^{(x + 0.5s^2 + sH/\sqrt{n-1})}$$

where:

UCL	=	95 percent upper confidence limit of estimated mean
e	=	constant (base of natural log, approximately equal to 2.718)
x	=	arithmetic mean of log-transformed data
s	=	standard deviation of log-transformed data
H	=	H-statistic
n	=	number of samples

In calculating the 95 percent UCLs, non-detects will be assigned a concentration equal to one-half the sample quantification limit (SQL). If an SQL is not available one of the following values will be substituted - the method detection level or the contract required quantitation limit (CRQL) for organics, or contract required detection limit (CRDL) for inorganics. For chemicals detected at least once in a particular medium, one-half the SQL will be used to represent non-detects when calculating arithmetic averages. For duplicate pairs that have one detect and one non-detect reported, the detect will be used to represent that location.

Harding ESE will complete RAGS Part D Table 3, which summarizes EPCs for COPCs for each exposure point, following regional and national guidance on the EPC term listed above.

4.3.4 Quantification of Exposures

The next step is to calculate COPC intakes, via consumption of fish and other biota, for each of the potentially exposed populations. Population-related variables will be selected that describe the characteristics associated with individual receptors in that population. For example, intake is dependent upon contact rate, age, body weight, body surface area, exposure frequency, exposure

duration, and averaging time. When possible, variables such as age and body weight will be selected from USEPA guidance documents, including The Exposure Factors Handbook (USEPA, 1997a).

The general equation for calculating chemical intake from consumption of biota is:

$$\frac{C \times CR \times EF \times ED \times CF}{BW \times AT}$$

where:

C	=	chemical concentration, biota
CR	=	consumption rate, media specific
EF	=	exposure frequency, population specific
ED	=	exposure duration, population specific
CF	=	conversion factor, media specific
BW	=	body weight of hypothetically exposed individual
AT	=	averaging time (for carcinogens, AT=70 years x 365 days per year; for noncarcinogens, AT=ED x 365 days per year).

Intakes for consumption of fish and other biota will be calculated per Section 6 of RAGS (USEPA, 1989a).

The exposure profiles identifying potential receptors, potential exposure points, exposure medium and route, frequency of exposure, duration of the exposure event, and duration of the exposure period will be described in the risk assessment. Exposure parameters that will be used in the risk assessment will be representative of RME and CT exposures. The risk assessment report will present the exposure parameters and equations used to calculate risk in sufficient detail to enable calculations to be verified by USEPA, USACE, and Battelle reviewers.

4.3.5 Consumption Patterns

Primarily, values from the literature for general fish consumption parameters (assuming recreational and subsistence fishing occurs at the site) will be used. Literature values may be default USEPA exposure parameters or values from published studies and published biota consumption surveys for locally caught fish and biota. Preference will be given to information from highly populated cities in the northeast.

4.4 TOXICITY ASSESSMENT

The toxicity assessment will evaluate the available evidence on the potential adverse effects associated with exposure to each analyte. With this information, a relationship between the extent of exposure and the likelihood or severity of adverse human health effects will be developed. Two steps are typically associated with toxicity assessment: hazard identification and dose-response assessment.

Hazard identification identifies adverse effects that have been associated with exposure to an agent and, more importantly, whether those effects will occur in humans. Characterizing the nature and strength of causation is also a part of the hazard identification step. The HHRA will contain a toxicity profile for selected COPCs at the site. Toxicity profiles will describe the physical and toxicological properties of contaminants.

A dose-response assessment will be conducted to characterize and quantify the relationship between intake, or dose, of a COPC and the likelihood or severity of a toxic effect, or response. There are two major types of toxic effects that will be evaluated in the risk assessment: carcinogenic and noncarcinogenic.

Following USEPA guidance (USEPA, 1989a), these two endpoints will be evaluated separately. For carcinogens, USEPA weight-of-evidence classifications and numerical toxicity factors have been developed and have undergone extensive peer review. Toxicity information that will be used in the toxicity profile will be primarily from: Integrated Risk Information System (IRIS), Health Effects Assessment Tables (HEAST), Agency for Toxic Substances and Disease Registration (ATSDR) Toxicology Profiles, and the USEPA Environmental Criteria and Assessment Office.

Cancer Toxicity Values

Toxicity factors for carcinogenic analytes include cancer slope factors (CSFs) and weight-of-evidence classifications for all carcinogens. For confirmed human carcinogens (USEPA Class A), the cancer type observed in exposed humans will be identified. A CSF is used to express the dose-response relationship. The HHRA for this site will provide the relevant information such as the CSF as well as identify the critical study on which each value is based, cancer type identified in the study, and weight-of-evidence classification.

TEFs for Carcinogenic PAHs

Carcinogenic PAHs are a class of compounds with very similar, complex heterocyclic structures. Only one PAH, benzo(a)pyrene, has a published USEPA CSF. For the other carcinogenic PAHs, the toxicity has been addressed by using TEFs published by USEPA (USEPA, 1992). The TEFs identify the relative potency of each compound relative to that of benzo(a)pyrene. The CSF for benzo(a)pyrene is used for other carcinogenic PAHs, adjusted by the appropriate relative potency factor. TEFs will be used only in estimating the cancer risk associated with these compounds and will not be used to estimate the noncancer risks.

Noncancer Toxicity Values

The Reference Dose (RfD) is an estimate of a daily human intake, including sensitive subpopulation that is likely to be without appreciable risk of deleterious effects during a lifetime. Most RfDs for COPCs will be obtained from IRIS or HEAST. Separate sets of RfDs have been developed by USEPA for evaluating chronic and subchronic exposures. In general, chronic RfDs will be used when the exposure duration is greater than seven years.

Identifying Toxicity Values for Coplanar (Dioxin-Like) PCBs, Dioxin/Furans and Hexachloroxanthene

USEPA will be the primary source of toxicity information used to evaluate risks associated with PCB congeners and dioxin-like compounds. For dioxins and furans, information from the USEPA dioxin reassessment (to be completed) will be used. In the interim, IRIS and HEAST toxicity values and TEFs from the World Health Organization (WHO) and Van den Berg et al. (1998) may be used. The TEFs for dioxin-like PCBs, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) identified for mammals will be applied to the fish tissue exposure point concentrations for each of the congeners to identify a toxic equivalence concentration (TEQ). The TEQ will be used in conjunction with the oral cancer slope factor for 2,3,7,8-TCDD (available in HEAST, USEPA 1997e) to estimate cancer risk for those compounds. The dioxin-like PCB congeners to be evaluated in this manner include congeners 105, 114, 118, 123, 156, 157, 167, 189, 81, 77, 126, and 169. The remainder of the PCB congeners will be evaluated using the High Risk and Persistence, Upper Bound cancer slope factor. The reference dose (Aroclor 1254) obtained from the IRIS database will be used to evaluate non-cancer risks associated with PCBs.

USEPA Region I has requested that the Office of Research and Development recommend dose-response values for HCX for use in the HHRA. Planned in-vitro toxicity studies to be conducted

as part of the ecological risk evaluation will provide additional information concerning HCX toxicity.

Toxicity information will be presented in the RAGS Part D Tables 5 and 6 for noncancer and cancer endpoints, respectively.

4.5 RISK CHARACTERIZATION

The final step of the risk assessment is the risk characterization. This step will involve the integration of the exposure and toxicity assessment into quantitative expressions of potential human health risks associated with COPC exposure. Quantitative estimates of both carcinogenic and noncarcinogenic risks will be made for each COPC and each exposure point.

Cancer Risks

Carcinogenic risks associated with exposure to individual chemicals will be estimated by multiplying the chemical intake for each carcinogen by its CSF. This value represents an upper bound of the probability of an individual developing cancer over a lifetime as the result of exposure to a chemical. For consumption of biota, the chemical-specific risks for all carcinogenic compounds will be summed to determine the lifetime cancer risk. The following equations will be used to estimate the chemical- and pathway-specific cancer risks.

Chemical-Specific Excess Lifetime Cancer Risk:

$$Risk_i = CDI_i \times CSF_i$$

where:

$Risk_i$	=	unitless probability of an individual developing cancer as the result of exposure to a chemical i
CDI_i	=	chronic daily intake of chemical i averaged over 70 years (mg/kg-day)
CSF_i	=	USEPA cancer slope factor for chemical i $(mg/kg\text{-}day)^{-1}$

Pathway-Specific Incremental Lifetime Cancer Risk:

$$Risk_T = \Sigma\ Risk_i$$

where:

$Risk_T$	=	unitless probability of an individual developing cancer as the result of multiple chemical exposures

$Risk_i$ = unitless cancer risk estimate for a single chemical associated with biota consumption

The results from the carcinogenic risk assessment will be compared to acceptable risk ranges established by the USEPA. The USEPA's guidelines, established in the National Hazardous Substances and Pollution Contingency Plan (NCP) identify acceptable exposure levels as those concentration levels "that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response" (USEPA 1989a).

Noncancer Risks

Noncancer risk estimates will be calculated by dividing specific chemical intake by the appropriate RfD. The result is called the hazard quotient (HQ). The HQs for individual compounds within an exposure pathway are summed to obtain the hazard index (HI) for that particular pathway.

Following are the equations used to determine the HQs and HIs.

The following equation is used to determine the hazard quotient:

$$HQ_i = \frac{I_i}{RfD_i}$$

where:

HQi	=	hazard quotient of chemical i
Ii	=	intake of chemical i averaged over the exposure period (mg/kg-day)
RfDi	=	reference dose for chemical i corresponding to the same exposure duration as the intake (mg/kg-day)

The following equation is used to determine the hazard index:

$$HI = \Sigma\ HQ_i$$

where:

HI	=	potential for noncarcinogenic effects from multiple chemical exposures
HQi	=	hazard quotient for each chemical associated with biota consumption

An HI of less than 1 indicates that noncarcinogenic toxic effects are unlikely. An HI greater than 1 indicates a greater possibility of a noncarcinogenic toxic effect occurring, but the circumstances must be evaluated on a case-by-case basis. Generally, as the HI increases, so does the likelihood that adverse effects might be associated with exposure. However, the relationship between increased risk and larger HI values may not linear.

4.6 UNCERTAINTY ANALYSIS

Uncertainties in the quantification of risk associated with the site will be identified and their impacts on risk estimates will be discussed in a separate section of the HHRA. The HHRA will include a discussion of major limitations of the analyses, any sources of uncertainties, and, if possible, any indication as to whether these uncertainties and limitations may have resulted in and over- or under-estimation of risk. The uncertainty section may also include unusual site conditions or extenuating circumstances that may be pertinent to risk management decisions. Other factors such as the inadequacy of toxicity factors to describe all possible COPC-receptor interactions and individual differences within the human population may be included in this section.

4.7 CONCLUSIONS AND RECOMMENDATIONS

The potential risks will be determined and compared to Superfund risk management criteria. Risks associated with future biota consumption patterns from the portion of the river within the boundaries of the site will be determined to assess the need for remediation. If appropriate, remediation goals for COPCs in sediment will be developed, as discussed below in Section 4.8.

4.8 CALCULATION OF PRELIMINARY REMEDIATION GOALS

The results and conclusions of the baseline risk assessment will identify the chemicals that most significantly contribute to human health risks for the fish consumption pathway. For those chemicals in fish tissue that are associated with an excess lifetime cancer risk greater than one-in-one-million and/or a noncancer hazard quotient greater than 0.1, biota tissue concentrations associated with various risk levels (cancer risk of 10^{-6}, 10^{-5}, 10^{-4}, and hazard quotients of 0.1, 1, and 10) will be identified for the conservative fish consumption scenario.

Site-specific, chemical-specific, Biota-Sediment Accumulation Factors (BSAFs) will be developed from lipid-normalized tissue data and total organic-carbon normalized sediment concentrations as described in Appendix D.

The sediment PRGs for human health will be derived by dividing the risk-specific tissue concentrations by BSAFs. The sediment PRGs will be presented in a separate document that contains an assessment of fish consumption risks at the two reference locations as well as the sediment PRGs for human heath and ecological risk.

5.0 BASELINE ECOLOGICAL RISK ASSESSMENT

This Section describes the approach that will be used to characterize ecological risks in each of the aquatic environments and associated floodplains downgradient of the source area. This Work Plan describes the methodology for evaluating the biological and chemical data collected as part of the site investigation activities, and estimating potential ecological risks. Specifics concerning sampling methodologies and location of samples to be collected in support of the BERA will be outlined in the forthcoming SAP.

The proposed approach for conducting the BERA is consistent with the following guidance documents:

- *Ecological Risk Assessment Guidance for Superfund, Process for Designing and Conducting Ecological Risk Assessments* (Process Document) (USEPA, 1997d);
- *Guidelines for Ecological Risk Assessment* (USEPA, 1998b);
- *Framework for Ecological Risk Assessment* (USEPA, 1992d); and
- *Risk Assessment Guidance for Superfund - Environmental Evaluation Manual* (USEPA, 1989c).

The objective of the BERA is to determine whether exposure to site-related contaminants detected in surface water, sediment, floodplain sediment/soil, bank soil/sediment, and groundwater samples (to be collected during RI field activities) poses an unacceptable risk to ecological receptors at the Site. If warranted, information developed in the BERA will also be used to support development of ecologically-based PRGs.

An eight-step approach consisting of two tiers is presented in the Process Document (USEPA, 1997d) and has been adopted the Site. Assessments completed at either step have essentially the same structure: problem formulation, analysis, risk characterization, and uncertainty analysis. The primary difference between the tiers is the level of complexity and the number/types of additional studies incorporated into the assessment.

The first tier, a screening ecological risk assessment (SERA) which includes Steps 1 and 2 identified in the Process Document, has been completed at the Site (TetraTech NUS Inc., 2000a). The SERA was based on a literature search and screening evaluation of ecological risks from exposures to contaminants in site media, using available ecotoxicological benchmarks and/or regulatory standards. Exposure pathways considered in the SERA included:

- Invertebrate communities exposed to surface water, sediment, and floodplain soil;
- Piscivorous mammal and bird populations exposed to floodplain soil and sediment;
- Insectivorous mammal and bird populations exposed to floodplain soil and sediment; and

- Herbivorous mammal and bird populations exposed to floodplain soil and sediment.

Potential risks for these receptors were evaluated by comparing maximum concentrations to conservative screening benchmarks. Based on this screening, the following environmental media and classes of compounds were identified as requiring further evaluation:

- Bank Sediment/Soils: dioxins/furans, metals, SVOCs, and pesticides/PCBs;
- Floodplain Sediment/Soils: dioxins/furans, metals, SVOCs, pesticides/PCBs, and herbicides;
- Aquatic Sediment: dioxins/furans, metals, SVOCs, and pesticides/PCBs;
- Source Area Surface Water: dioxins/furans, metals (filtered and unfiltered), and pesticides;
- Floodplain Surface Water: dioxins/furans, and metals (filtered and unfiltered); and
- Downstream Surface Water: dioxins/furans, metals (filtered and unfiltered), SVOCs, and pesticides.

Environmental samples collected from Allendale Pond and Lymansville Pond exceeded screening benchmarks by the greatest frequency and magnitude (TetraTech NUS Inc., 2000a). Therefore, a BERA was recommended, with additional data collection activities focused on these two ponds. Further information about the SERA is provided in Appendix C of the EE/CA report (Tetra Tech NUS Inc., 2000a).

This BERA, which consists of Steps 3 through 8 of the Process Document, represents the second tier of the Process Document approach (USEPA, 1997d) and includes:

- Refining the objectives (i.e., assessment endpoints) of the BERA based on the results of the Step I evaluation;
- Developing a workplan and SAP outlining additional data collection activities specifically designed to meet identified objectives;
- Verifying implementability of proposed studies for the Site;
- Collecting additional data; and,
- Conducting the baseline assessment of ecological risk at the Site (USEPA, 1997d).

The Process Document identifies scientific management decision points (SMDPs) throughout the BERA process where preliminary results are discussed with the project team. The USEPA, the National Oceanic and Atmospheric Administration (NOAA), RIDFW, and U.S. Fish and Wildlife Service (USFWS), are integral partners in planning the RI and BERA for the Site and will be involved throughout the process. The components of the BERA (including problem

formulation, analysis, risk characterization, and uncertainty analysis) are discussed in greater detail in the following subsections.

5.1 PROBLEM FORMULATION

The problem formulation for the BERA will consist of a review and update of the preliminary formulation presented in the SERA. A preliminary CSM was developed as part of the initial risk screening and has been refined to reflect changes in the scope of the study area (Figure 4). Detailed rationale for the selected assessment and measurement endpoints that are the focus of the BERA will be provided in the problem formulation.

5.1.1 Data Evaluation and Identification of Contaminants of Potential Concern

The problem formulation will discuss available data and identify the contaminants that are likely to be of most concern in aquatic sediment, floodplain soil, and sediment/surface water based on the history of releases from the source area. Additional data collection activities are described in Section 3 and specific procedures for implementing these tasks will be provided in the SAP.

Using the data from existing samples and samples to be collected as part of the field sampling activities, summary statistics will be generated for each medium for both the site and background and/or reference samples. Bank soil (and sediment) and floodplain sediment (and soil) will be combined for the purposes of evaluating ecological exposures. A summary of statistics will be generated separately for this group and the aquatic sediment. Exposed floodplain sediment (or soil) locations that will be flooded following restoration of Allendale Dam will be grouped with the aquatic sediment medium to evaluate baseline conditions.

Statistics will be reported only for detected analytes, and will include: the frequency of detected analytes; the range of sample quantitation limits (SQLs), the arithmetic average, the minimum and maximum detected concentrations; and the 95 percent UCL on the log-transformed arithmetic average. Concentrations of dioxins, furans, and coplanar PCB compounds will be expressed in terms of an equivalent concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin by multiplying each detected congener concentration by Toxicity Equivalency Factors (TEFs) (Van den Berg et al., 1998). Sediment and floodplain soil will be considered to be from 0 to 1 foot below ground surface.

5.1.1.1 Data Summarization

The following guidelines will be used in summarizing the data. Rejected data will be excluded from the data set. Duplicate pairs will be averaged prior to generating summary statistics. For chemicals detected at least once in a particular medium, one-half the SQL will be used to

represent non-detects when calculating arithmetic averages. For duplicate pairs that have one detect and one non-detect reported, the detect will be used to represent that location. These data summary procedures are consistent with USEPA guidance.

5.1.1.2 Selection of Contaminants of Potential Concern

The COPCs identified for the surface water, sediment, and floodplain soil media will consist of the COPCs identified in the screening assessment. To simplify the assessment, floodplain and bank sediment and soil media will be combined as a single exposure medium, referred to as "floodplain soil." In addition, existing floodplain sediment analytical data will either be combined with the floodplain soil or river sediment media for the exposure assessment although future conditions will also be considered (e.g., proposed remedy for Allendale Pond) depending on whether aquatic or terrestrial exposures are more likely to occur.

COPCs will also be selected for site groundwater and biota tissue prior to conducting the analysis phase of the BERA. Groundwater COPCs will be identified by comparing available groundwater data and VDS sample results to ecological surface water screening benchmarks. For biota tissue, COPCs will be selected by comparing the maximum tissue concentrations to the lowest applicable CBRs and benchmark for wildlife. If the maximum tissue concentration is below the lowest applicable CBR or wildlife benchmark, the chemical will not be selected as a COPC and not be carried further in the BERA process. The benchmark values used to screen COPCs will be based on measured mortality, growth, or reproductive effects as defined in the assessment endpoints.

5.1.2 Selection of Receptors

The receptors that are likely at risk from exposure to contaminated media from the Site include aquatic receptors (including plants, invertebrates, fish, and juvenile amphibians) exposed to sediment and surface water, and semi-aquatic receptors (including plants, invertebrates, mammals, birds, reptiles, and amphibians) exposed to floodplain soil or contaminated prey. Based on the USEPA scope of work, the BERA will be focused on evaluating effects on the following ecological receptor groups (receptors that will be specifically evaluated in the BERA are indicated in parentheses). These species were selected based on documented occurrence within the study area and/or specific dietary preferences that are anticipated to maximize potential bioaccumulation hazard posed by Site COPCs. It is assumed that each of these species is representative of other species within a given trophic level or guild.

- Aquatic invertebrates (general community typical of a warm water fishery habitat);
- Terrestrial invertebrates (e.g., earthworms);
- Demersal, omnivorous fish (e.g., white sucker);

- Pelagic, piscivorous or semi-piscivorous fish (e.g., largemouth bass);
- Piscivorous wildlife (e.g., river otter, kingfisher, great blue heron);
- Insectivorous wildlife (e.g., tree swallow, short-tailed shrew, American Woodcock, little brown bat); and
- Omnivorous wildlife (mallard, raccoon).

In addition, information received from the RIDEM Bureau of Natural Resources (BNR) and the USFWS concerning potential occurrences of rare, threatened, or endangered species, and critical habitats of concern will be provided special consideration.

5.1.3 Site Conceptual Model

As a first step in the problem formulation phase, a conceptual model has been developed based on consideration of the ecological community or components potentially at risk, stressor characteristics, and exposure pathways. The exposure scenarios evaluated in the conceptual site model consider contaminant sources, environmental transport mechanisms, partitioning of the analytes between various environmental media, identification of exposure routes, and the types of ecological receptors that could be potentially exposed. The ecological conceptual site model is provided as Figure 4.

5.1.4 Selection of Assessment and Measurement Endpoints

An important step in the problem formulation process is the identification of assessment and measurement endpoints, which must be completed before exposure, toxicity, or risk can be estimated. Endpoints are used in the BERA to define the ecological attributes to be protected (assessment endpoints) and to define measurable characteristics of those attributes that can be used to gauge the degree of impact that may occur (measurement endpoints).

A typical assessment endpoint is an ecological attribute that, if found to be significantly affected, would indicate a need for remediation. Assessment endpoints most often relate to attributes of biological populations or communities (e.g., abundance, richness, and productivity). Individual-based assessment endpoints typically are relevant only if endangered species are present.

In general, the assessment endpoints for the BERA are the protection and maintenance of aquatic, semi-aquatic, and terrestrial receptor populations at the Site. The overall objective of the BERA is to determine if exposure to contaminant concentrations detected in site media is likely to cause a decline in receptor populations or to adversely affect the integrity of aquatic or floodplain soil communities. The general types of effects of concern include:

- Mortality, growth, or reproductive effects resulting from direct exposure to contaminants that affect a significant proportion of a receptor population;
- Mortality, growth, or reproductive effects resulting from exposure to contaminants that have bioaccumulated in the ecological food chain that affect a significant proportion of a (higher trophic level) receptor population; and,
- Indirect effects associated with a substantial reduction in abundance of prey populations.

Tables 5-1 through 5-6 summarize these endpoints for the Centredale Manor Site, their objective, and identified data requirements. Narrative descriptions of each of these assessment endpoints will be provided in the BERA. These assessment endpoints will be measured using a variety of field and laboratory tests that are described in Section 3.0. The bioaccumulation hazard posed by persistent biological toxicants (PBTs), including dioxins, furans, HCX, PCBs, and pesticides, will be evaluated by comparing measured tissue concentrations to CBRs and foodweb exposure modeling.

5.2 ANALYSIS

The analysis phase consists of an exposure assessment, in which exposures are identified and quantified, and an effects assessment, in which toxicological effects associated with COPCs are identified. The literature-derived and site-specific effects data used to gauge the risk to receptors will also be described. Tables 5-1 through 5-6 identify the measurement endpoints in terms of potential measures of exposure and/or measures of effects for ecological receptors.

5.2.1 Measures of Exposure and Effect by Receptor Group

Tables 5-1 through 5-6 present the assessment and measurement endpoints for each of the receptor groups listed in Section 5.2.1.1 that will be evaluated in the ERA. The magnitude of potential contaminant exposures for these receptor groups will be estimated and measured using a variety of techniques and the measurement endpoints relating to ecological effects are also summarized. These endpoints are outlined below and prioritized according to the inference weight that has been assigned.

Aquatic and Floodplain Invertebrate Communities (Assessment Endpoint #1)

- Measured concentrations of COPCs in the tissue of field caught emergent aquatic macroinvertebrates and floodplain soil macroinvertebrates to determine uptake and bioavailability. The tissue chemical results will also be used in food chain models to

determine ingestion doses for wildlife receptors that feed on these invertebrates. Table 5-1, numbers 4 and 5; *Medium to High* Inference Weight.

- Chronic and/or life cycle toxicological response of laboratory animals exposed to whole sediment collected from the Woonasquatucket River. Evaluate presence of correlations between COPC concentration and biological response to identify potential stressors. Table 5-1, number 3; *Medium to High* Inference Weight.
- Relationship between measures of aquatic macroinvertebrate community structure and function and surface water and sediment COPCs and nutrients. Focused on potential effects associated with discharging groundwater and discriminating impacts from non-Site related stressors. Table 5-1, number 6a; *Medium to High* Inference Weight.
- Relationship between aquatic sediment chemistry and aquatic insect productivity and community structure as measured by emerging adults. Table 5-1, number 6b; *Medium to High* Inference Weight.
- Relationship between floodplain sediment chemistry and soil infauna productivity and community structure as measured by emerging adults. Table 5-1, number 7; *Medium to High* Inference Weight.
- Comparison of surface water and sediment COPC concentrations with aquatic effects criteria/guidelines to provide measure of effect. Table 5-1, numbers 1 and 2; *Low to Medium* Inference Weight.

Demersal, Omnivorous Fish Populations (Assessment Endpoint #2)

- Measure the concentrations of COPCs in the tissue of field caught fish to determine uptake and bioavailability. The tissue chemical results will also be used in food chain models to determine ingestion doses for wildlife receptors that feed on these fish. Compare to CBRs to provide measure of effect. Table 5-2, number 2a; *High* Inference Weight.
- Measure COPC concentrations in fish eggs dosed in the laboratory with a synthetic mixture of dioxin-like compounds similar in composition of field fish tissue. Direct measure of effect to a sensitive receptor. Table 5-2, number 3; *High* Inference Weight.
- Estimate fish tissue concentrations COPCs using measured sediment concentrations and BSAFs. Compare to CBRs will provide a measure of effect. Table 5-2, number 2b; *Low to Medium* Inference Weight.
- Fish surveys to compare health of populations evaluating differences in demographic structure, health of individual fish, and species richness and relative abundance between impacted reaches and reference areas. Table 5-2, number 1; *Low to Medium* Inference Weight.

Pelagic, Piscivorous and Semi-Piscivorous Fish Populations (Assessment Endpoint #3)

- Measured concentrations of COPCs in tissue of field caught fish to determine uptake and bioavailability. The tissue chemical results will also be used in food chain models to determine ingestion doses for wildlife receptors that feed on these fish. Comparison to CBRs to provide a measure of effect. Table 5-3, number 2a; *High* Inference Weight.
- Estimate the fish tissue concentrations of COPCs using measured surface water and sediment concentrations and BSAFs. Comparison to CBRs will provide a measure of effect. Table 5-3, number 2b; *Low to Medium* Inference Weight.
- Fish surveys to compare health of populations evaluating differences in demographic structure, health of individual fish, and species richness and relative abundance between impacted reaches and reference areas. Table 5-3, number 1; *Low to Medium* Inference Weight.

Piscivorous Mammal and Bird Populations (Assessment Endpoint #4)

- Estimate dietary doses of sediment COPCs using food chain models. Input parameters will be based on measured tissue concentrations of prey items and literature-derived exposure factors (e.g., receptor-specific ingestion rate, body weight, home range, and dietary composition). Comparison of estimated doses to literature-derived TRVs will provide a measure of effect. Table 5-4, number 1; *Medium* Inference Weight.
- Estimate tissue residues of COPCs using measured sediment and prey tissue analytical results, and literature-derived trophic transfer factors. Compare to CBRs will provide a measure of effect. Table 5-6, number 2; *Medium* Inference Weight.
- Conduct on-site surveys of the piscivorous mammal and bird populations at each of the sampling areas noting breeding activities, foraging habits, and frequency of use. Potential measure of exposure and effect if substantial disparities between study area habitats and similar reference areas are noted Table 5-4, number 3; *Low* Inference Weight.

Insectivorous Mammal and Bird Populations (Assessment Endpoint #5)

- Measure the concentrations of COPCs in the tissue of field caught tree swallow nestlings and eggs to determine uptake and bioavailability. Compare to CBRs to provide a measure of effect. Table 5-5, number 2a; *High* Inference Weight.
- Compare swallow nest productivity and reproductive success between study area sites and reference area to provide a measure of effect. Table 5-5, number 2a; *High* Inference Weight.

- Estimate tissue residues of COPCs in tree swallows and/or eggs using emergent insect tissue and sediment chemistry, and trophic transfer factors. Compare to CBRs to provide a measure of effect. Table 5-5, number 2a; *High* Inference Weight.
- Estimate dietary doses of sediment and floodplain soil COPCs using food chain models. Input parameters will be based on measured tissue concentrations of prey items and literature-derived exposure factors. Compare estimated doses to literature-derived TRVs to provide a measure of effects. Table 5-5, number 1; *Medium* Inference Weight.
- Estimate tissue and/or egg residues of COPCs using measured sediment and/or floodplain soil chemical results, prey item tissue chemical results, and literature-derived trophic transfer factors. Comparison to CBRs will provide a measure of effect. Table 5-5, number 2b; *Medium* Inference Weight.
- Conduct on-site surveys of the mammal, bird, and calling amphibian populations at each of the sampling areas to confirm the insectivorous species that are present; if possible, note breeding activities, foraging habits, and frequency of use. Potential measure of exposure and effect if substantial disparities between study area habitats and similar reference areas are noted. Table 5-5, number 4; *Low* Inference Weight.

Omnivorous Mammal and Bird Populations (Assessment Endpoint #6)

- Estimated dietary doses of COPCs using food chain models. Input parameters will be based on measured tissue concentrations of prey items and literature-derived exposure factors (e.g., receptor-specific ingestion rate, body weight, home range, and dietary composition). Compare estimated doses to literature-derived TRVs to provide a measure of effects. Table 5-6, number 1; *Medium* Inference Weight.
- Estimate tissue residues of COPCs using measured sediment and prey item tissue results, and literature-derived trophic transfer factors. Comparison to CBRs will provide a measure of effect. Table 5-6, number 2; *Low to Medium* Inference Weight.
- Conduct on-site surveys of the mammal and bird populations at each of the sampling areas noting breeding activities, foraging habits, and frequency of use. Potential measure of exposure and effect if substantial disparities between study area habitats and similar reference areas are noted. Table 5-6, number 3; *Low* Inference Weight.

5.2.2 Exposure Assessment

The purpose of the ecological exposure assessment is to evaluate the likelihood and magnitude of ecological receptor exposures to contaminated media in the Woonasquatucket River and associated impounded areas. The ecological exposure assessment discusses the potential exposures defined in the problem formulation and measured in field and laboratory studies to

quantify exposure levels. Components of the exposure assessment include identification of ecological exposure pathways, and quantification of exposure.

The exposure points evaluated in the BERA will include the four lacustrine and two riverine areas discussed in Section 3.2. Exposure points within these areas will be further defined based on microhabitat features, such as optimal feeding or shelter area, preferred spawning habitat for fish, and/or deep water habitats.

5.2.2.1 Exposure Pathways

Figure 4 presents a summary of the complete exposure pathway for each receptor group for which assessment endpoints have been developed. The exposure pathways are summarized in Table 5-7. In general, aquatic organisms may be exposed to COPCs in sediment and surface water via direct dermal contact, and/or assimilation of, sediment-sorbed contaminants or contaminants in the water column. Contaminants may then enter the circulatory system via partitioning through respiratory epithelial tissues (e.g., gill membranes) or the gastrointestines following ingestion of contaminated food items. Both invertebrates and vertebrates, such as fish, in direct contact with surface water or sediment may serve as contaminant vectors for indirect exposure to higher trophic levels through food chain transfer.

Semi-aquatic and terrestrial wildlife receptors that forage on aquatic prey or prey associated with floodplain and bank habitat of the Woonasquatucket River may be exposed to contamination through several exposure pathways (Figure 3). These pathways include dermal contact with surface water, sediment, or soil; incidental ingestion of sediment or soil; consumption of drinking water, and ingestion of prey items that have bioaccumulated or bioconcentrated contaminants in their tissue.

5.2.2.2 Development of Exposure Point Concentrations

In general, 95 percent UCLs (see Section 4.3.3) and average concentrations will be used to represent exposure point concentrations for each COPC. These statistics will be generated for surface water, aquatic sediment, sediment and soil associated with flood plain and bank areas, and tissue data stratified by exposure area. In cases where the 95 percent UCL is greater than the maximum detected concentration, the maximum concentration will be used to represent the upper bound exposure concentration. Exposure point concentrations for COPCs with dioxin-like effects (i.e., dioxins, HCX, furans, and certain coplanar PCBs) will be estimated as the average or 95 percent UCL of the toxicity equivalence concentrations according to the methodology outlined in Attachment C.

To estimate exposures to wildlife, the daily dose received from each applicable exposure pathway will be estimated and combined as a total daily dose (in mg/kg/day) for a given COPC. The exposure pathways that will be quantified for wildlife in the BERA include surface water ingestion, incidental sediment or soil ingestion, and consumption of contaminated prey in diet. The following equations will be used to estimate these exposures.

Surface Water Ingestion Pathway. The receptor-specific average daily dose (ADD_{water}), expressed in mg/kg/day, will be estimated as the quotient of the mass of a given COPC ingested on a daily basis and the body mass of the receptor being evaluated:

$$ADD_{water} = \frac{(COPC_{water} * IR_{water})}{BW} * (SFF)$$

where:

ADD_{water}	=	Daily dose of a COPC from consuming surface water (mg/kg/day);
$COPC_{water}$	=	Average exposure concentration (mg/L) in surface water;
IR_{water}	=	Water ingestion rate (L/day) for wildlife receptor;
SFF	=	Site Foraging Frequency (unitless) which represents the fraction of the exposure area relative to the home or forage range of the receptor; and,
BW	=	Body weight (kg) of receptor

Incidental Sediment/Soil Ingestion Pathway. The receptor-specific average daily dose ($ADD_{sediment}$), expressed in mg/kg/day on a dry weight basis, will be estimated for each receptor as follows:

$$ADD_{sediment} = \frac{(COPC_{sediment} * PD_{sediment} * IR_{total})}{BW} * (SFF)$$

where:

$ADD_{sediment}$	=	Daily dose of a COPC from incidental ingestion of sediment (mg/kg/day);
$COPC_{sediment}$	=	Average exposure concentration (mg/L) in sediment;
$PD_{sediment}$	=	Percent of sediment in overall diet (%);
IR_{total}	=	Total ingestion rate (L/day) for wildlife receptor;

SFF	=	Site Foraging Frequency (unitless) which represents the fraction of the exposure area relative to the home or forage range of the receptor; and,
BW	=	Body weight (kg) of receptor

This equation will also be used to estimate incidental soil ingestion exposures by terrestrial wildlife that forage in floodplain and bank habitats.

Contaminated Prey Consumption Pathway. The receptor-specific average daily dose (ADD_{diet}), expressed in mg/kg/day on a wet weight basis, will be estimated for each receptor as follows:

$$ADD_{diett} = ADD_{fish} + ADD_{inv}$$

where:

ADD_{diet}	=	Average or 95% UCL daily dietary dose of a given COPC in diet;
ADD_{fish}	=	Average or 95% UCL daily dietary dose of a given COPC from consumption of fish; and,
ADD_{inv}	=	Average or 95% UCL daily dietary dose of a given COPC from consumption of invertebrates.

The average daily dose of a COPC that a given receptor receives from the portion of its diet represented by fish, expressed on a wet weight basis, will be estimated as follows:

$$ADD_{fish} = \frac{(COPC_{fish} * PD_{fish} * IR_{total})}{BW} * (SFF)$$

where:

ADD_{fish}	=	Daily dose of a COPC from ingestion of fish (mg/kg/day);
$COPC_{fish}$	=	Average or 95% UCL exposure concentration (mg/L) in fish;
PD_{fish}	=	Percent of fish in overall diet (%);
IR_{total}	=	Total ingestion rate (L/day) for wildlife receptor;
SFF	=	Site Foraging Frequency (unitless) which represents the fraction of the exposure area relative to the home or forage range of the receptor; and,
BW	=	Body weight (kg) of receptor

The average daily dose of a COPC that a given receptor receives from the portion of its diet represented by invertebrates, expressed on a wet weight basis, will be estimated as follows:

$$ADD_{inv} = \frac{(COPC_{inv} * PD_{diet} * IR_{total})}{BW} * (SFF)$$

where:

ADD_{inv}	=	Daily dose of a COPC from ingestion of invertebrates (mg/kg/day);
$COPC_{inv}$	=	Average or 95% UCL exposure concentration (mg/L) in invertebrates;
PD_{inv}	=	Percent of invertebrates in overall diet (%);
IR_{total}	=	Total ingestion rate (L/day) for wildlife receptor;
SFF	=	Site Foraging Frequency (unitless) which represents the fraction of the exposure area relative to the home or forage range of the receptor; and,
BW	=	Body weight (kg) of receptor

The receptor-specific exposure parameters, including dietary composition, daily ingestion rates, body weight, and foraging range) will be tabulated. Food and water ingestion rates will be estimated using allometric equations which relate food and water intake to body weight of the receptor species, as presented in the *Wildlife Exposure Factors Handbook* (USEPA, 1993a). Information on the dietary composition for specific receptor species will be obtained from a variety of sources. The amount of each prey item ingested daily (kg/day) will be calculated by multiplying the food ingestion rate (kg/day) by the percentage of the diet comprised by each prey item. The incidental soil or sediment ingestion rate for some receptors will also be based on data presented in the *Wildlife Exposure Factors Handbook* (USEPA, 1993a), or on professional judgment.

A Site Foraging Frequency (SFF) will be used to estimate the percentage of time the indicator species will forage in a particular area based on the animal's home range and the exposure area. The SFF will be estimated by dividing the receptor's home range by the area of contamination; by definition, the SFF cannot exceed 1.

Average daily dose estimates for each representative wildlife receptor will be tabulated and presented in the BERA.

5.2.2.3 Development of Biota/Sediment Accumulation Factors

BSAFs will be developed for all exposure areas where biological tissue data are available. BSAFs are be derived as the ratio of the average lipid-normalized concentration in tissue to the average organic carbon-normalized concentration in sediment (USEPA, 1993a) for a defined exposure area. The derived BSAFs will be multiplied by the TOC-normalized sediment EPCs to estimate tissue concentrations in biota in exposure areas where site-specific tissue data are not available (i.e., Manton and Dyerville Ponds). BSAFs presented in the ecological literature will also be summarized to provide a corroboration of the site-specific BSAFs.

5.2.3 Effects Assessment

This section of the BERA will identify and describe the measurement endpoints used to measure potential effects to aquatic and semi-aquatic receptors, including: regulatory criteria/guidelines and other ecotoxicological benchmarks; site-specific toxicity or community studies that will be implemented at the site as described in Section 3; site-specific tissue concentration data; and CBRs. These endpoints are discussed in general terms below.

5.2.3.1 Toxicological Benchmarks

Toxicological benchmarks used to screen COPCs in surface water, sediment, floodplain soil, and fish tissue will be derived from the literature. The values selected will be based on growth, reproductive, or mortality endpoints for plants, soil invertebrates, and/or wildlife.

Surface water. Surface water benchmarks include: chronic Ambient Water Quality Criteria (AWQC) (USEPA, 1998c; 1991d); chronic RIDEM AWQC (RIDEM, 2000); chronic freshwater ecotoxicity thresholds (ETs) (USEPA, 1996c); lowest observed effects levels (LOELs) from the Aquatic Information Retrieval (AQUIRE) database; and other readily available sources.

Sediment. Sediment benchmarks include the USEPA equilibrium partitioning-based sediment guidelines (ESGs) for endrin, dieldrin, and total PAHs and consensus-based freshwater sediment quality guidelines from MacDonald et al., 2000.

Floodplain Soil. Floodplain soil benchmarks were derived from a variety of literature sources, and include plant benchmarks (Efroymson et al., 1997a; Hulzebos et al., 1993), and soil invertebrate benchmarks (Efroymson et al., 1997b; Vonk et al., 1986; Neuhauser et al., 1985 and 1986; Hans et al., 1990; Reinecke and Venter, 1985; USEPA, 1985; Bouche et al., 1987; van Gestel and van Dis, 1988; Malecki et al., 1982; and Molnar et al., 1989).

Fish Tissue. Fish tissue benchmarks for screening COPCs will be calculated using data presented in the ORNL *Toxicological Benchmarks for Wildlife* (Sample et al., 1996). In addition, the information provided in Jarvinen and Ankley (1999) and in the ERED database (COE-Vicksburg, 2001).

5.2.3.2 Toxicity Studies

Toxicity tests will be used to measure the potential effects on field and/or laboratory raised organisms from exposure to site media. The following toxicity tests are proposed for the Site and are described in further detail in Section 3.3:

- Chronic and/or subchronic whole sediment toxicity tests measuring survival, growth, and reproductive effects on sediment benthos; and,
- Partial life-cycle tests involving naïve unfertilized fish eggs dosed with a synthetic mixture of dioxins, furans, HCX, and coplanar PCBs designed to simulate the chemical composition of fish tissue from the Woonasquatucket River.

5.2.3.3 Field Population and Community Studies

Field population and community studies will be implemented to evaluate potential population-level effects (e.g., survival, growth, or reproduction) or community-level effects (e.g., species richness and abundance) associated with exposure to site media. The following population and/or community studies are described in further detail in Section 3.3.2:

- Macroinvertebrate community evaluation and habitat assessment in riverine habitats per the Rapid Bioassessment Protocol (RBP) (Barbour et al., 1999);
- Aquatic macroinvertebrate emergence study (including measures of enumeration and abundance of emerging adults);
- Floodplain macroinvertebrate community integrity study (including measures of enumeration and abundance);
- Fish population surveys of ecological integrity (including measures of species richness and abundance); and
- Tree swallow reproductive success survey.

5.2.3.4 Critical Body Residues

Both measured and modeled tissue concentrations will be compared with published CBRs (Jarvinen and Ankley, 1999; COE-Vicksburg, 2001) to determine the potential effects to

ecological receptors. Body burden effects will be evaluated for the following ecological receptors using the methodology generally described above:

- Aquatic macroinvertebrates exposed to contaminants in sediment;
- Floodplain macroinvertebrates exposed to contaminants in floodplain soil;
- Fish egg and adult fish (demersal omnivorous and pelagic piscivorous/semi-piscivorous) exposures to sediment; and
- Piscivorous, insectivorous, and omnivorous wildlife exposures to floodplain soil.

5.2.3.5 Toxicity Reference Values

Acute and chronic ingestion studies will be used to estimate dose levels that are not anticipated to result in adverse impacts to the modeled indicator wildlife receptors. Computer databases (e.g., IRIS, ECOTOX, DIALOG) will be searched for recent toxicological information, and additional sources of relevant information include primary literature, compilations of toxicological data, and various governmental publications. These data will be used to evaluate the potential toxicity of the estimated exposure levels for each major taxonomic group of ecological receptors. Toxicity Reference Values (TRVs) will be developed for each indicator receptor following the guidelines presented in Attachment C. TRVs for 2,3,7,8-TCDD will be developed for comparison to derived Toxic Equivalents.

5.3 RISK CHARACTERIZATION

The BERA will combine the results of the exposure and effects assessments in a weight-of-evidence approach to characterize the risks to ecological receptors from exposure to COPCs. Tables 5-1 through 5-6 present the qualitative inference weights that will be assigned to each measurement endpoint.

The decisions regarding overall risk to ecological receptors will be made by considering various lines of evidence from the results of all components of the assessment (i.e., the approach will integrate results of physical, biological, and toxicological studies to draw risk-based conclusions). A qualitative weight of evidence approach will be employed to integrate multiple measurement endpoints in making conclusions about the likelihood of risks to the selected indicator organisms. The BERA will identify chemical risk drivers and specific locations of concern that pose a significant risk of harm to ecological receptors. This information will be used to support response action decisions for the site. The BERA approach and risk conclusions will be summarized and the spatial extent of each exposure area that poses an unacceptable risk to ecological receptors will be presented graphically.

5.4 UNCERTAINTY ASSESSMENT

The interpretation of risk estimates is subject to a variety of uncertainties that result from the use of conservative assumptions and the lack of necessary information to quantify actual exposure and effects concentrations (Hicks et al., 1995). Variability in both measures of exposure and effect will be quantified and presented throughout the BERA. The field efforts described above are intended to minimize the uncertainties by providing site-specific measures of exposure and effects. Uncertainties associated with the BERA will be identified and the potential implications they have for the conclusions of the assessment will be discussed.

5.5 CALCULATION OF PRELIMINARY REMEDIATION GOALS

The chemicals that most significantly contribute to ecological risks for each evaluated exposure pathway will be identified in the BERA. As the BERA is primarily a residue-based evaluation focused on the bioaccumulation hazard posed by dioxin-like compounds, it is anticipated that that the most significant risks will be associated with the presence of these compounds in biological tissue. Biota tissue concentrations associated with hazard quotients of 0.1, 1, and 10 will be identified for each pertinent receptor group for which that biota tissue represents an exposure pathway. For instance, protective fish tissue concentrations that are estimated to pose the given hazard range will be identified based on evaluation of the risks to the fish themselves (i.e., CBR comparison), to progeny (i.e., ELS bioassay), and to piscivorous birds and mammals (i.e., food chain modeling). Tissue concentrations that are protective of all evaluated receptor groups will be identified and site- and chemical-specific BSAFs will be developed from the lipid-normalized tissue data and total organic carbon-normalized sediment concentrations as described in Appendix D. PRGs will be derived by dividing the risk-specific tissue concentrations by these BSAFs. It is possible that PRGs will also be required for non residue-based endpoints (e.g., macroinvertebrate community structure). PRGs will be estimated for the most significant potential stressors using a combination of benchmark comparison and correlations between observed effects and concentration.

Ecologically-based sediment PRGs will be compared to the similar human health PRGs and the recommendations concerning the need for possible remedial actions within each exposure area will be provided.

AQUIRE	Aquatic Information Retrieval
ATSDR	Agency for Toxic Substance and Disease Registration
AVS	Acid volatile sulfides
AWQC	Ambient Water Quality Criteria
BERA	Baseline Ecological Risk Assessment
BNR	Bureau of Natural Resources
BSAFs	biota/sediment accumulation factors
CBR	critical body residues
CDI	chronic daily intake
CLP	contract laboratory procedures
COPCs	chemicals of potential concern
CRDL	contract required detection limit
CRQL	contract required quantitation limit
CSF	cancer slope factors
CSM	conceptual site model
CT	central tendency
EE/CA	Engineering Evaluation/Cost Estimate
ELS	early life stages
EPC	exposure point concentrations
ERL	effects range-low
ESG	equilibrium partitioning-based sediment guidelines
ET	ecotoxicity threshold
HCX	hexachloroxanthene
HEAST	health effects assessment tables
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IBI	Index of Biotic Integrity
IRIS	Integrated Risk Information System
LELs	lowest effect levels
LOED	lowest observed effect dose
LOELs	lowest observed effects dose

NCP	National Hazardous Substances and Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOED	no observed effect dose
OHM	oil and/or hazardous materials
OME	Ontario Ministry of the Environment
PAHs	polycyclic aromatic hydrocarbons
PBTs	persistent biological toxicants
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
PPB	part per billion
PRB	Rapid Bioassessment Protocol
PRGs	preliminary remediation goals
RAGS	Risk Assessment Guidance for Superfund
RfD	reference dose
RIDEM	Rhode Island Department of Environmental Management
RIDFW	Rhode Island Department of Fish and Wildlife
RIDOH	Rhode Island Department of Health
RME	reasonable maximum exposure
RBP	rapid bioassessment protocol
SAP	Sampling and Analysis Plan
SEM	simultaneously extracted metals
SERA	screening ecological risk assessment
SMOPs	scientific management decision parts
SQLs	sample quantitation limits
SVOCs	semivolatile organic compounds
TCL	target compound list
TEF	toxicity equivalency factors
TEQ	toxic equivalence concentration
TOC	total organic carbon
TRVs	toxicity reference values
UCL	upper confidence level
USACE	United States Corps of Engineers
USEPA	United States Environmental Protection Agency

USFWS	United States Fish and Wildlife Service
VDS	vapor diffusion sampling
VOCs	volatile organic compounds
WHO	World Health Organization

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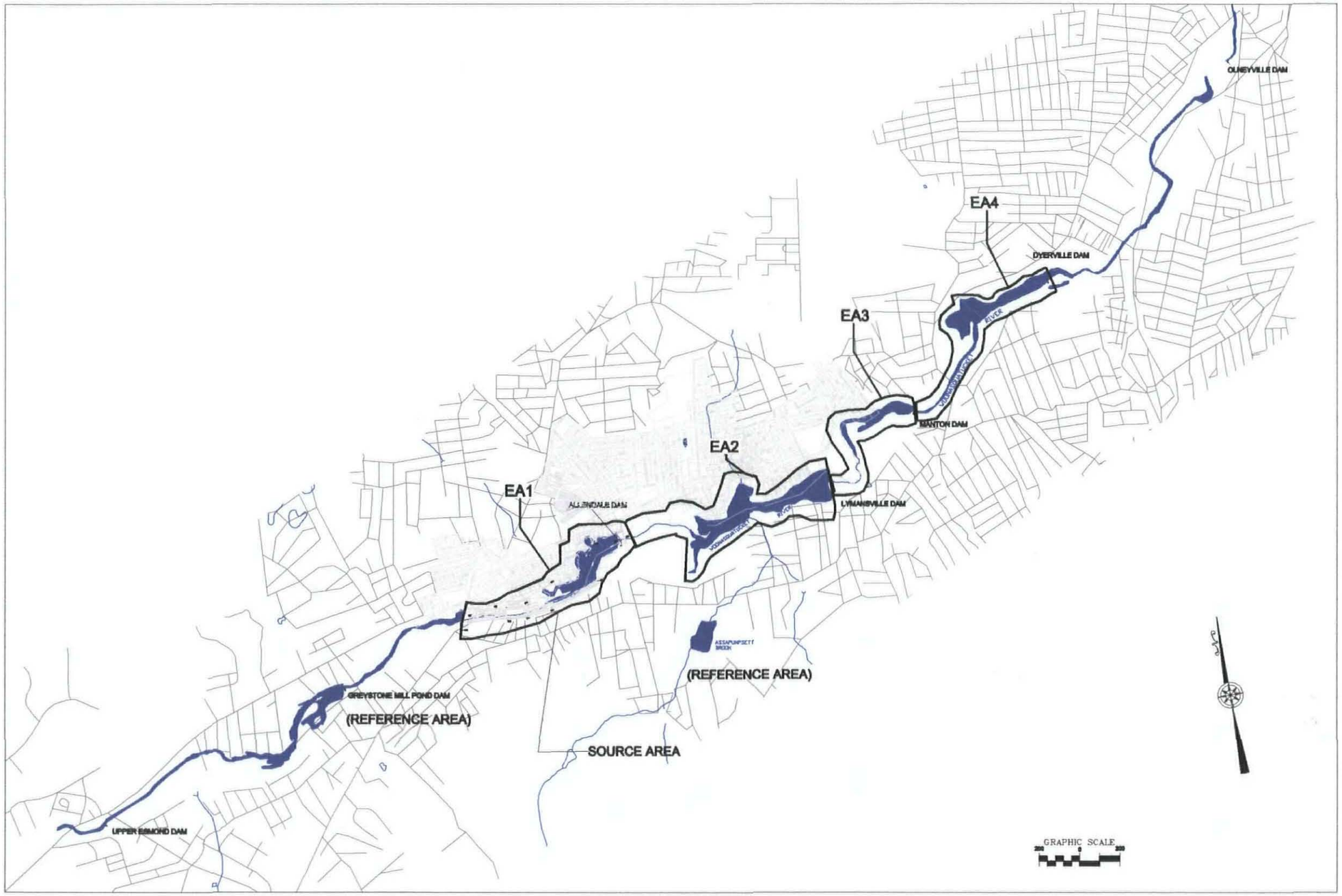


LEGEND:

EA = EXPOSURE AREA

= SURFACE WATERS

= APPROXIMATE EXTENT OF EXPOSURE AREAS

* EA1, EA2, EA3, AND EA4 constitute the site.

SOURCE: TetraTech

Harding ESE
A MACTEC Company

Original includes color coding.

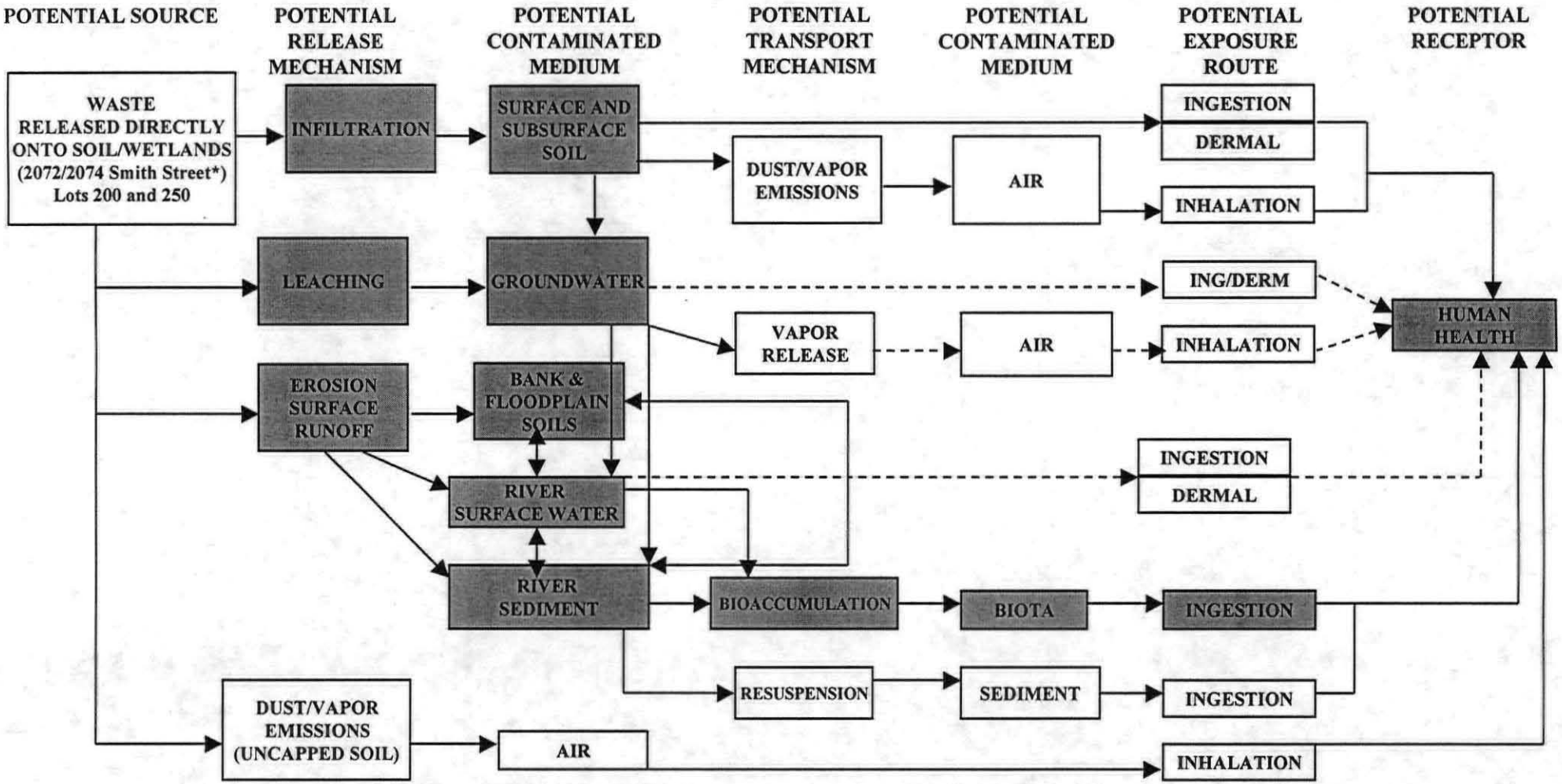
FIGURE 1
SITE LAYOUT AND EXPOSURE AREAS
CENTERDALE MANOR RESTORATION SITE
NORTH PROVIDENCE, RHODE ISLAND

ENTERDALE2.DWG

Figure 2a

HUMAN HEALTH SITE CONCEPTUAL MODEL: SOURCE 1

Centredale Manor Restoration Site
North Providence, Rhode Island



* Occupied by Brook Village andCentredale Manor apartment buildings.

Note: Media, release/transport mechanisms, and exposure routes associated with the human health pathway of concern (consumption of fish and other biota) are shaded.

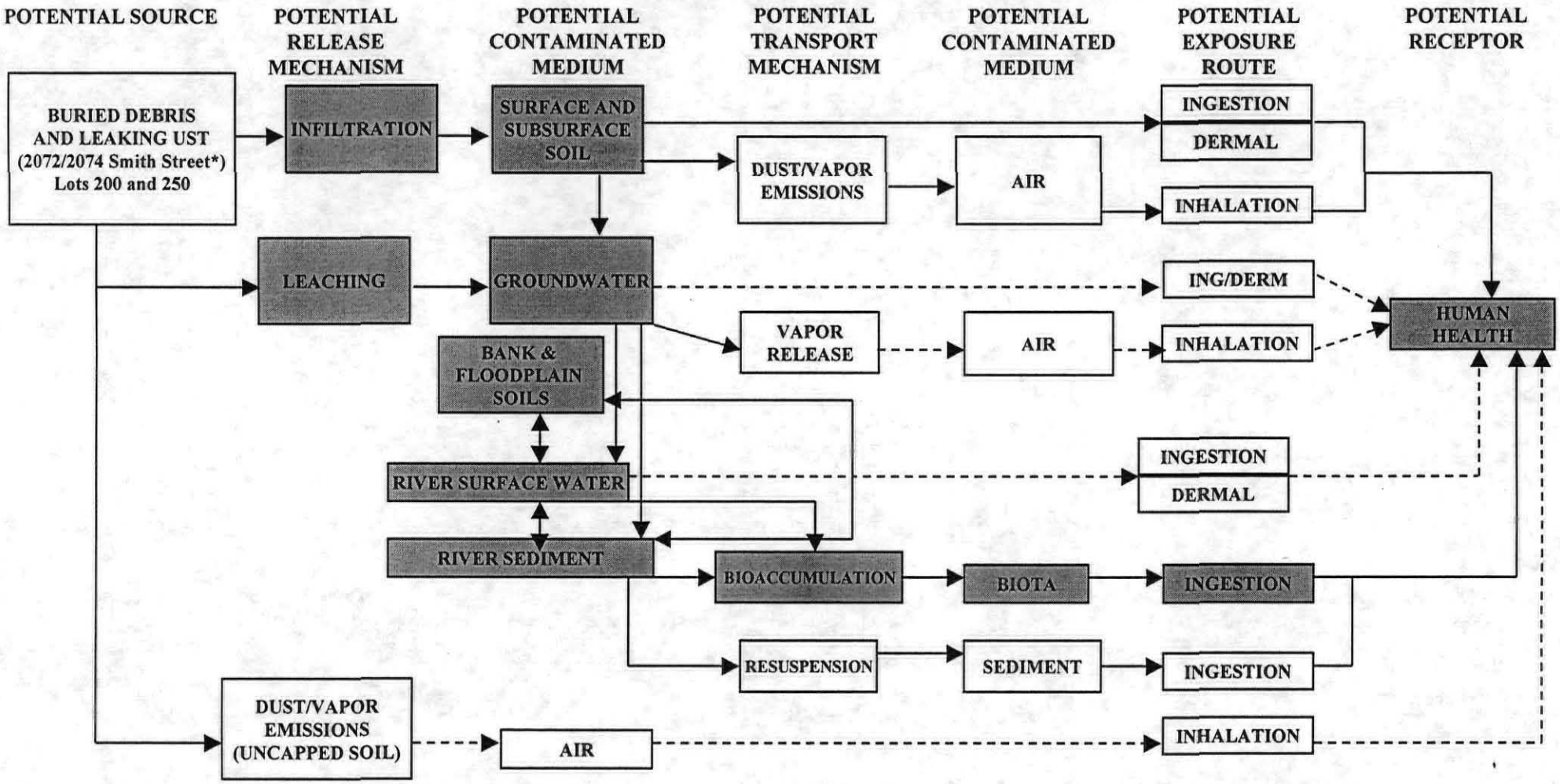
——————— Potentially significant pathway

– – – – – – – – Unlikely to be a significant pathway

Figure 2b

HUMAN HEALTH SITE CONCEPTUAL MODEL: SOURCE 2

Centredale Manor Restoration Site
North Providence, Rhode Island



* Occupied by Brook Village and Centredale Manor apartment buildings.

Note: Media, release/transport mechanisms, and exposure routes associated with the human health pathway of concern (consumption of fish and other biota) are shaded.

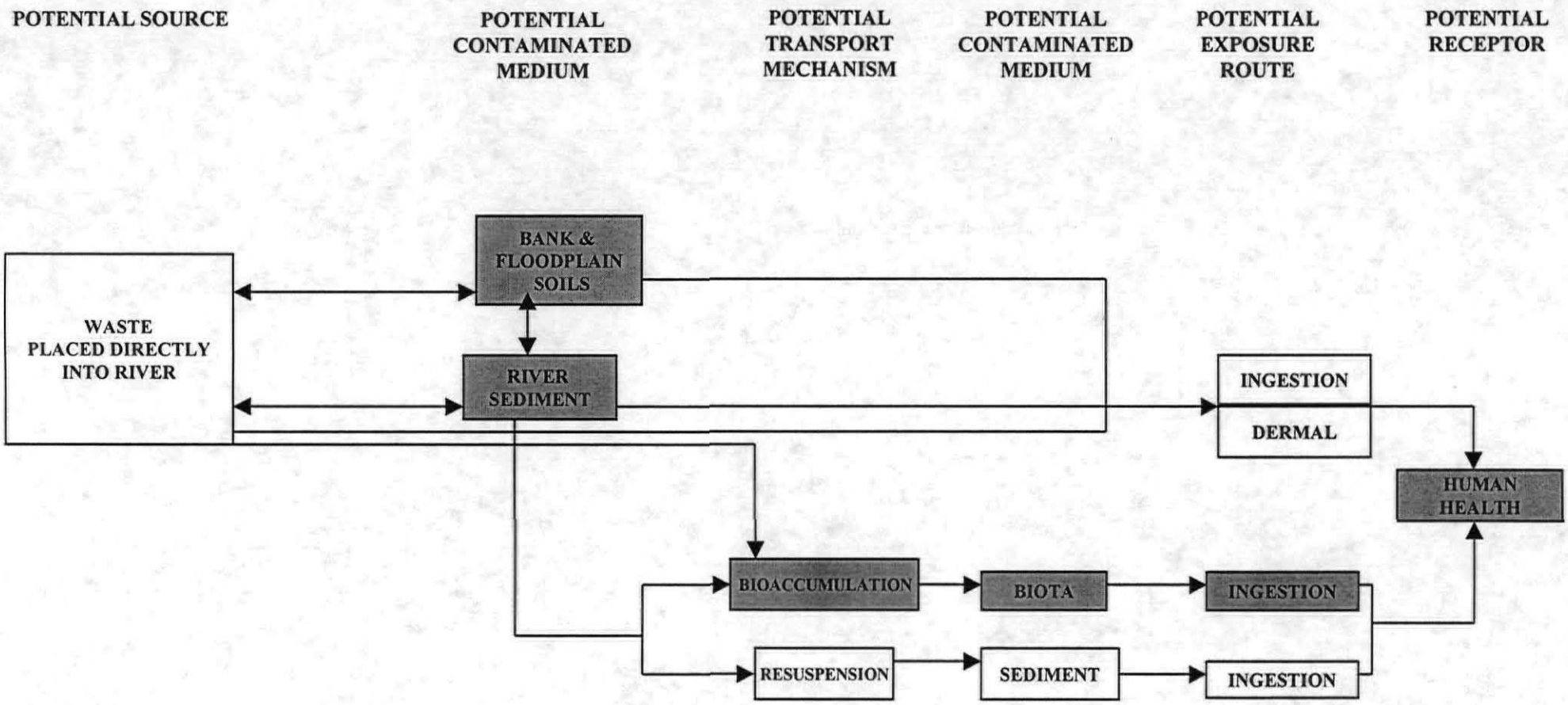
——————— Potentially significant pathway

– – – – – – – Unlikely to be a significant pathway

Figure 2c

HUMAN HEALTH SITE CONCEPTUAL MODEL: SOURCE 3

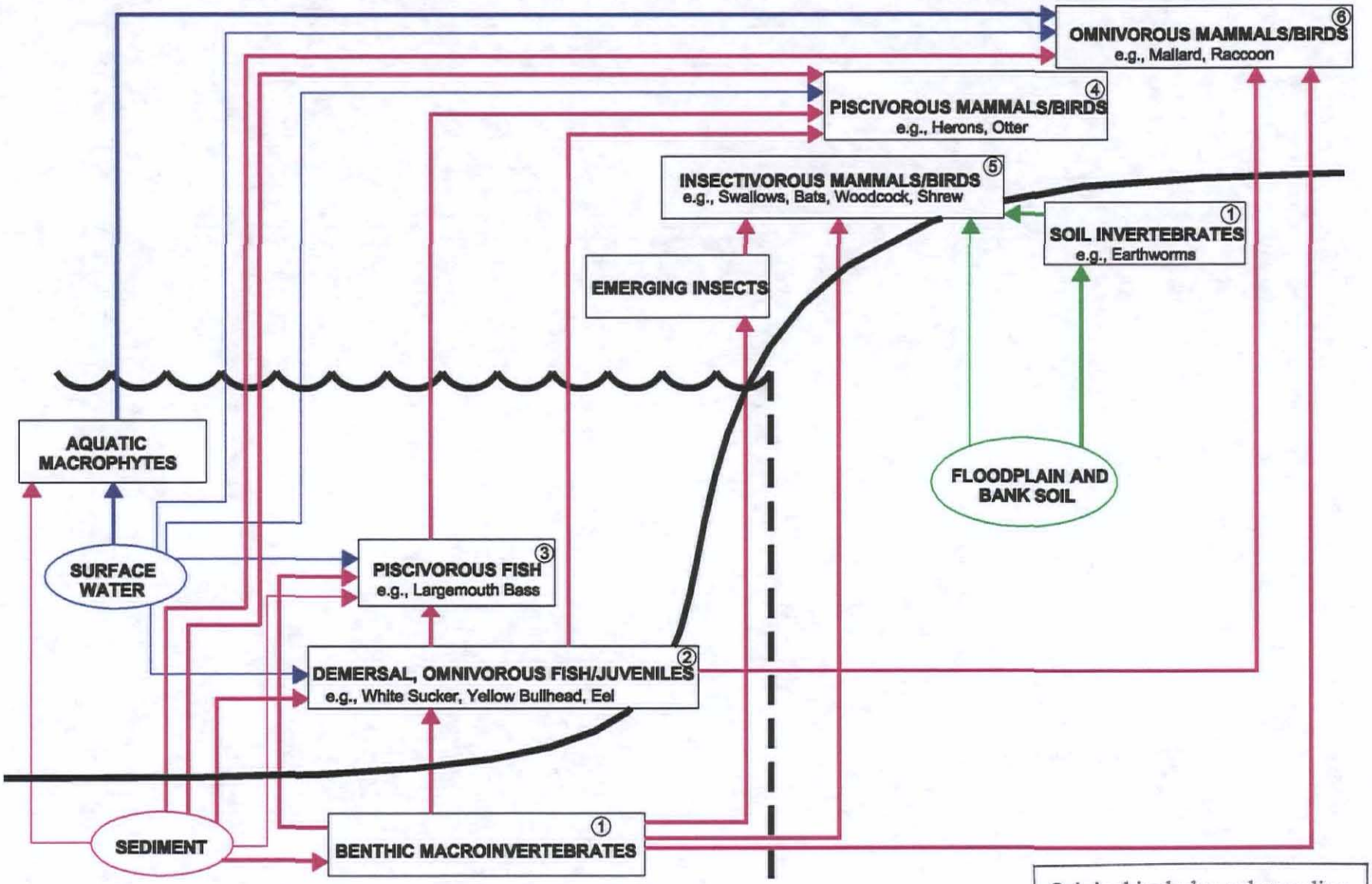
Centredale Manor Restoration Site
North Providence, Rhode Island



* Occupied by Brook Village andCentredale Manor apartment buildings.
Note: Media, release/transport mechanisms, and exposure routes associated with the human health pathway of concern (consumption of fish and other biota) are shaded.

——————— Potentially significant pathway

- - - - - - - - Unlikely to be a significant pathway



Original includes color coding.

NUMBERS ① THROUGH ⑥ REFER TO THE ASSESSMENT ENDPOINTS DEFINED IN TABLES 5-1 THROUGH 5-6.

PRIMARY TRANSPORT PATHWAY

SECONDARY TRANSPORT PATHWAY

Harding ESE
A MACTEC Company

FIGURE 3
GENERALIZED ECOLOGICAL FOOD CHAIN

CENTERDALE MANOR RESTORATION SUPERFUND SITE
NORTH PROVIDENCE, RHODE ISLAND

CENTERDALE5.DWG

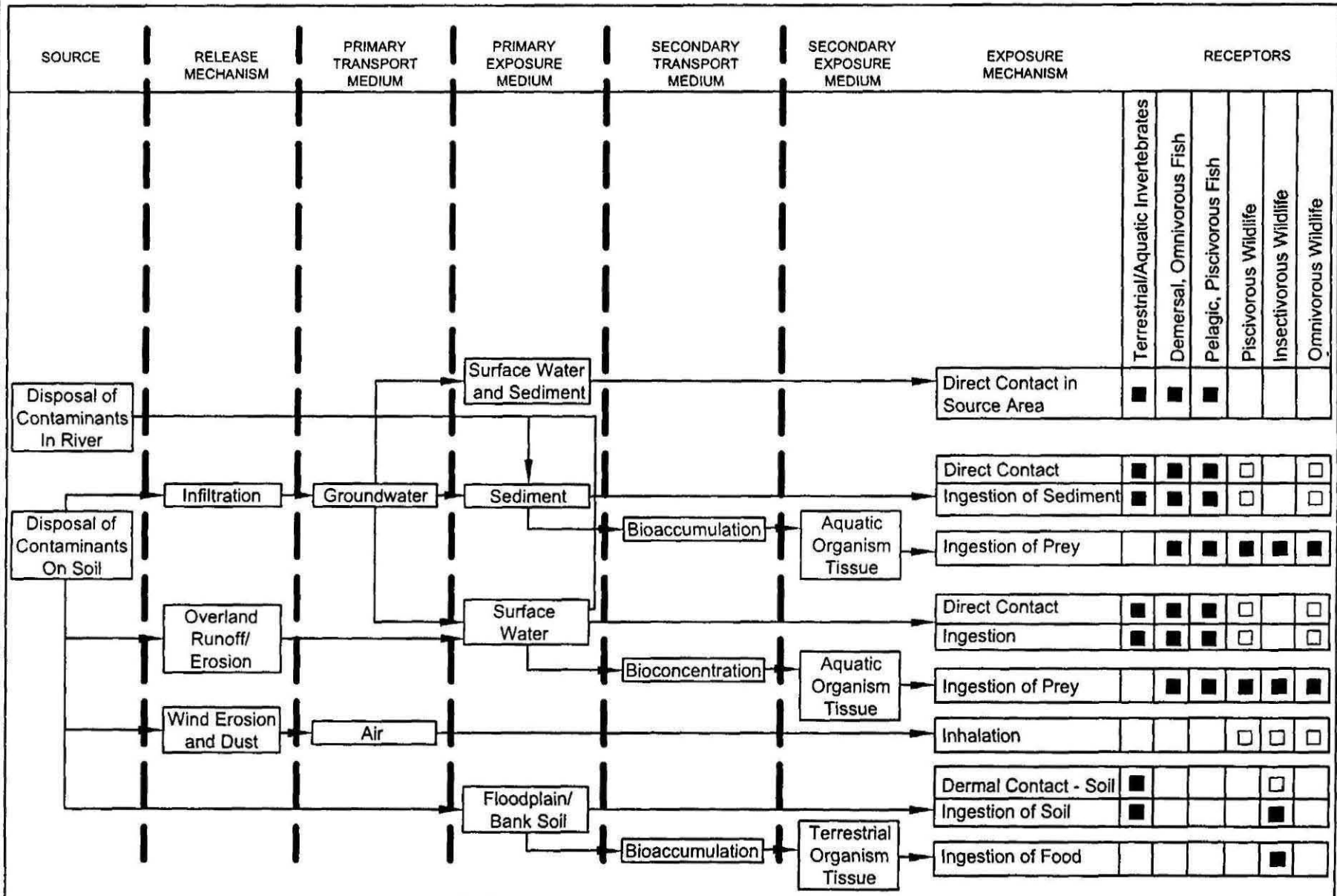


FIGURE 4
ECOLOGICAL CONCEPTUAL SITE MODEL

CENTERDALE MANOR RESTORATION SUPERFUND SITE
NORTH PROVIDENCE, RHODE ISLAND

CENTERDALE6.DWG

Table 3-1

Number of Samples with Analytical Results by Exposure Area

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Allendale Reach:

Matrix & Submatrix	Number of Samples with Analytical Results [1]								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	3	3	-	3	-	3	-	-
Floodplain (FP)	-	9	9	9	20	-	16	-	20
Aquatic (SD)	-	22	22	21	22	1 [2]	21	-	22
Surface Water	-	13	13 [3]	-	13	-	13	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	29	29	-	-	-	96	29	-
Bank (BK)	-	-	-	-	-	-	3	-	-
Floodplain (FP)	3	3	3	-	3	-	76	3	-
Aquatic (SD)	1	36	36	-	42	-	95	30	5

Lymansville Reach:

Matrix & Submatrix	Number of Samples with Analytical Results [1]								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	15	15	-	13	-	15	-	-
Floodplain (FP)	-	5	-	-	10	-	10	-	10
Aquatic (SD)	-	14	14	13	14	-	14	-	14
Surface Water	-	21	21 [4]	-	21	-	20	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	33	33	-	33	-	109	-	-
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	-	-	-	-	-	-	-	-

See notes at end of table.

Table 3-1

Number of Samples with Analytical Results by Exposure Area

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Manton Reach:

Matrix & Submatrix	Number of Samples with Analytical Results *								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	10	9	7	10	1 [4]	10	-	9
Surface Water	-	-	-	-	-	-	-	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	-	-	-	-	-	-	-	-
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	-	-	-	-	-	-	-	-

Dyerville Reach:

Matrix & Submatrix	Number of Samples with Analytical Results *								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	6	4	3	6	1 [2]	6	-	6
Surface Water	-	-	-	-	-	-	-	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	-	-	-	-	-	-	-	-
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	-	-	-	-	-	-	-	-

See notes at end of table.

Table 3-1

Number of Samples with Analytical Results by Exposure Area

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Upgradient (In the Area of Greystone Mill Pond):

Matrix & Submatrix	Number of Samples with Analytical Results *								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	6	6	-	6	-	6	-	-
Floodplain (FP)	-	7	2	2	10	-	10	-	10
Aquatic (SD)	-	3	3	3	3	-	3	-	3
Surface Water	-	3	3 [3]	-	3	-	3	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	-	-	-	-	-	-	-	-
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	-	-	-	-	-	-	-	-

See notes at end of table.

Table 3-1

Number of Samples with Analytical Results by Exposure Area

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Assapumpsett Brook/Pond:

Matrix & Submatrix	Number of Samples with Analytical Results *								
	VOCs	SVOCs	Metals	AVS/SEM	Pesticides/ PCBs	PCB Congeners	Dioxins/ Furans	Herbicides	TOC
Sediment									
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	1	1	1	1	-	1	-	1
Aquatic (SD)	-	2	2	2	2	-	2	-	2
Surface Water	-	-	-	-	-	-	-	-	-
Soil (<1 foot bgs)									
Residential (RES)	-	-	-	-	-	-	-	-	-
Bank (BK)	-	-	-	-	-	-	-	-	-
Floodplain (FP)	-	-	-	-	-	-	-	-	-
Aquatic (SD)	-	-	-	-	-	-	-	-	-

Notes:

[1] Information based on data base prepared by Tetra Tech NUS provided in January 2001.

[2] PCB congener 77

[3] Total and dissolved

[4] PCB congeners 77, 126, 169

Matrices are in bold and each submatrix is listed below the matrix.
Samples not incorporated above: Allendale Race or samples located along the west bank of the river.
Does not imply that full suite analyses were performed.

PCB — Polychlorinated Biphenyl
SVOC — Semivolatile Organic Compound
TOC — Total Organic Carbon
VOC — Volatile Organic Compound

Table 3-2

Number of Samples and Analyses Required by Exposure Area

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

		Reference Area		*Exposure Area*					Required Analyses															
Matrix	Type	Greystone Mill Pond	Assapumpsett Brook	Allendale Reach	Lymansville Reach	Manton Reach [a]	Dyerville Reach [a]	Total # Samples	VOCs	SVOCs	TICs	PCBs/ Pesticides	Dalapon [b]	Metals	MeHg	Dioxins/ Furans (w/ HCX)	12 WHO PCBs	Hardness	TOC	Lipid	AVS/SEM	Grain Size	Percent Moisture	Nutrients [c]
Tissue	Fish - demersal	10	10	10	10	3	3	40	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Fish - piscivorous (fillet) [d]	10	10	10	10			46	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Fish - piscivorous (offal) [d]	10	10	10	10			40	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Other - fish, frog or turtle	10	10	10	10			40	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Subtotal - HHRA/ERA tissue	**40**	**40**	**40**	**40**	**3**	**3**	**166**																
Tissue	Crayfish	3	1	3	4	-	-	11	-	-	-	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Emerging insects	5	-	5	5	-	-	15	-	-	-	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Earthworms	3	1	3	4	-	-	11	-	-	-	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Subtotal - ERA only tissue	**11**	**2**	**11**	**13**			**37**																
Tissue	Swallow - eggs	5	-	5	5	-	-	15	-	-	-	✓	✓	-	-	✓	✓	-	-	✓	-	-	✓	-
	Swallow - nestlings	5	-	5	5	-	-	15	-	-	-	✓	✓	-	-	✓	✓	-	-	✓	-	-	✓	-
	Swallow - stomach contents	3	-	3	3	-	-	9	-	-	-	✓	✓	-	-	✓	✓	-	-	✓	-	-	✓	-
	Swallow - liver	5	-	5	5	-	-	15	-	-	-	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	✓	-
	Subtotal - swallow study	**18**		**18**	**18**			**54**																
Tissue	ELS - eggs	-	-	-	-	-	-	30	-	-	-	-	-	-	-	✓	✓	-	-	✓	-	-	✓	-
	ELS - synthetic mixture [e]	-	-	-	-	-	-	1	-	-	-	-	-	-	-	✓	✓	-	-	✓	-	-	✓	-
	ELS - fish tissue [e,f]	-	-	-	-	-	-	4	-	-	-	-	-	-	-	✓	✓	-	-	✓	-	-	✓	-
	Subtotal - ELS	**-**	**-**	**-**	**-**	**-**	**-**	**7**																
	Total Tissue	**69**	**42**	**69**	**71**	**3**	**3**	**264**																
Sediment	Crayfish locations	3	1	3	4	-	-	11	-	-	-	✓	✓	✓	✓	✓	✓	-	✓	-	✓	✓	✓	-
Sediment	Invertebrate bioassay [g]	1	1	3	3	-	-	8	-	✓	-	✓	✓	✓	✓	-	-	-	✓	-	✓	✓	✓	-
Surface Water		3	2	3	2	-	-	10	✓	✓	-	✓	✓	✓	-	-	-	✓	-	-	-	-	-	✓
Floodplain Soil		3	1	3	4	-	-	11	-	✓	-	✓	✓	✓	✓	✓	✓	-	✓	-	-	✓	✓	-

Notes:
[a] - A total of three samples will be collected in the Manton and Dyerville reaches. Species selection will be determined based on the fish community survey and risk assessment objectives.
[b] - Dalapon may be eliminated as a required analytical parameter following further evaluation of the bioaccumulation potential of this analyte.
[c] - Nutrients include various forms of nitrogen and phosphorous as specied in the QAPP.
[d] - It is assumed that only one category of fish tissue will require analysis of separate tissue fraction to support the human health and ecological risk assessment.
[e] - A complete analysis of PCB congeners will be required for the synthetic mixture and the fish tissue analysis components of the ELS.
[f] - Chemical composition of dioxin-like compounds in fish tissue from two species (preferable white sucker and catfish) will be required to develop the synthetic mixture.
[g] - Sediments will also be analyzed for the presence of ammonia prior to testing.
AVS/SEM - acid volatile sulfides/simultaneously extracted metals
ERA - ecological risk assessment
HHRA - human health risk assessment
ELS - early life stage
PCB - polychlorinated biphenyls
SVOC - semivolatile organic compound
TIC - tentatively identified compound
TOC - total organic carbon
VOC - volatile organic compound
WHO - World Health Organization

Table 3-3

Summary of Biological Data Needs, Sampling Areas, and Required Sample Sizes

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Study Type	Assessment Endpoint Number [a]	Measure of Effects [a]	Taxon	Exposure Area				
				Greystone Mill Pond Reach	Assapumpset Brook Reach	Allendale Pond Reach	Lymanville Pond Reach	Manton/ Dyerville Reach
Biological Tissue	1	4a	Aquatic macroinvertebrates (crayfish)	3	1	3	4	
	5	1	Emerging adult macroinvertebrates	5		5	5	
	1	5a	Earthworms	3	1	3	4 [b]	
	2	2a	Fish – demersal [c]	10	10	10	10	
	3	2a	Fish – piscivorous [c]	10	10	10	10	6 [c]
			Fish – other [c]	10	10	10	10	
	5	2a	Swallow – eggs	5		5	5	
	5	2a	Swallow – nestling	5		5	5	
	5	2a	Swallow – stomach content	3		3	3	
	5	2a	Swallow – liver	5		5	5	
Field Population and Community Studies [d]	1	6a	Aquatic macroinvertebrates	3	2	3	2 [e]	
	1	6b	Emerging adult macroinvertebrates	5		5	5	
	1	7	Floodplain soil fauna	3	1	3	4	
	2,3	1,1	Fish – IBI	2	1	2	2	

Table 3-3 (Continued)

Summary of Biological Data Needs, Sampling Areas, and Required Sample Sizes

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

Study Type	Assessment Endpoint Number [a]	Measure of Effects [a]	Taxon	Exposure Area				
				Greystone Mill Pond Reach	Assapumpset Brook Reach	Allendale Pond Reach	Lymanville Pond Reach	Manton/ Dyerville Reach
Field Population and Community Studies [d] (Cont)	2,3	1,1	Ichthyoplankton surveys	3	1	3	4	
	5	3	Swallow	1		1	1	
	4,5,6	3,4,3	Piscivorous, insectivorous, and omnivorous wildlife	1	1	1	1	
Toxicity Testing	1	3	Aquatic macroinvertebrates	1	1	3	3	
	2	4	ELS fish bioassay -- synthetic mixture exposure [f]					

Notes:

[a] From Tables 5-1 through 5-6.
[b] Sample collection will depend on habitat availability.
[c] Fish species and trophic status to be determined based on fish community survey and risk assessment objectives.
[d] Numbers refer to the number of discrete sampling units within each study reach.
[e] Samples will be collected from the lotic recovery area below Allendale Pond Dam.
[f] Fish samples (2 samples of 2 species, preferably white sucker and catfish) will be collected from Allendale Pond to determine composition of the synthetic mixture.

ELS – early life stage
IBI – Index of Biotic Integrity

Table 3-4

Summary of Proposed Biological Data Types and Data Quality Goals

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

DATA TYPE	INTENDED USE	DATA QUALITY GOALS
Aquatic macroinvertebrate tissue analytical data	Determine whether contaminant uptake poses a threat to the integrity of the macroinvertebrate community; provide input to wildlife exposure models.	Definitive data supported by rigorous QA/QC objectives, data reporting, and data validation.
Emerging adult macroinvertebrate tissue analytical data	Evaluate potential food chain risks to insectivorous wildlife based on assumption of exposure and effects.	Definitive data supported by rigorous QA/QC objectives, data reporting, and data validation.
Floodplain invertebrate tissue analytical data	*Determine whether contaminant* uptake poses a threat to the integrity of the floodplain soil community; provide inputs to wildlife exposure models.	*Definitive data supported by* rigorous QA/QC objectives, data reporting, and data validation.
Avifauna (eggs, nestling, and stomach contents)	Evaluated potential effects to insectivorous wildlife based on measured and estimated tissue concentrations.	Definitive data supported by rigorous QA/QC objectives, data reporting, and data validation.
Fish (demersal and piscivorous)	Provide data for the human health biota consumption risk assessment; provide input data for wildlife exposure models; identify spatial extent of exposure to sediment COCs; identify primary ELS stressors; contaminant bioaccumulation model calibration.	Definitive data supported by rigorous QA/QC objectives, data reporting, and data validation.
Aquatic macroinvertebrate community structure and function	Identify spatial extent of risk associated with groundwater discharge and non dioxin-like COCs in lotic environments; endpoint integrates exposures from chemical, physical (habitat) and nutrient stressors.	Qualitative data supplied in accordance with RIDEM and USEPA sample collection protocols and data evaluation procedures.
Emerging adult macroinvertebrate community structure and function	Identify potential forage base reduction; provides direct linkage to avifauna foraging/nesting and behavior data.	Qualitative and quantitative data supplied in accordance with RIDEM and USEPA sample protocols and data validation procedures.
Floodplain soil fauna community structure and function	Identify spatial extent of community level effects; identify potential forage based reduction.	Qualitative and quantitative data supplied in accordance with RIDEM and USEPA sample protocols and data validation procedures.
Fish community structure and function	Provide a measure of population-level effects that integrates across contaminants and exposure pathways.	Qualitative and quantitative data supplied in accordance with RIDEM and USEPA sample protocols and data validation procedures.

Table 3-4

Summary of Proposed Biological Data Types and Data Quality Goals

Human Health and Ecological Risk Assessment Work Plan
Centredale Manor Restoration Site
North Providence, Rhode Island

DATA TYPE	INTENDED USE	DATA QUALITY GOALS
Ichthyoplankton survey	Provide a measure of population-level effects that integrates across contaminants and exposure pathways.	Qualitative and quantitative data supplied in accordance with RIDEM and USEPA sample protocols and data validation procedures.
Tree swallow nest-box population survey	Provide a measure of population-level effects that integrates across contaminants and exposure pathways.	Qualitative and quantitative data supplied in accordance with RIDEM and USEPA protocols
Piscivorous, insectivorous, and omnivorous wildlife population integrity survey	Provide a measure of population-level effects that integrates across contaminants and exposure pathways.	Qualitative data supplied in accordance with RIDEM and USEPA protocols
Aquatic macroinvertebrate toxicity testing	Evaluate direct toxicological effect of sediment COCs to benthos; stressor identification; PRG development.	Qualitative and quantitative data generated at an off-site laboratory in accordance with published ASTM and USEPA procedures. Supported by rigorous laboratory documentation and technical review.
Fish toxicity testing (field caught and sediment elutriate exposed eggs)	Determine relationship between tissue concentrations and adverse ELS effects; fish population model parameterization; PRG development; provide a direct link between ELS effects and sediment COCs.	Qualitative and quantitative data generated at an off-site laboratory in accordance with published ASTM and USEPA procedures. Supported by rigorous laboratory documentation and technical review.

Table 5-1

Data Matrix For Assessment Endpoint #1
Protection and Maintenance of Aquatic and Floodplain Invertebrate Communities

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Comparison of surface water COC concentrations to criteria/guidelines	Exposure/Effect	Identify spatial extent of potential risk based on conservative screening	VOCs, SVOCs, PEST, INOR	Total/dissolved surface water analytical data; water hardness; criteria/guidelines for surface water COCs	x	x	x	x	x	Low - Medium	
2. Comparison of sediment COC concentrations to benchmarks/guidelines	Exposure/Effect	Identify spatial extent of potential risk based on conservative screening	All	Sediment analytical data; TOC and AVS:SEM data; benchmarks/ guidelines for sediment COCs	x	x	x	x	x	Low - Medium	
3. Whole sediment laboratory bioassays	Effect	Evaluate direct toxicological effect of sediment COCs to benthos; stressor identification; PRG development	SVOC, PEST, INOR	Sediment analytical data; TOC and AVS:SEM; benchmarks/ guidelines for sediment COCs	x	x	x	x		Medium - High	
4. Compare measured COC concentrations in aquatic macroinvertebrates to CBRs	Exposure/Effect	Determine whether contaminant uptake poses a threat to the integrity of the macroinvertebrate community; provide input to wildlife exposure models	PBT	Emerging adult insect tissue chemistry; lipid analysis; residue effects threshold values	x	x	x	x		Medium - High	Derived trophic transfer factors used to extrapolate effects to lower reach
5. Compare measured COC concentrations in floodplain macroinvertebrates to CBRs	Exposure/Effect	Determine whether contaminant uptake poses a threat to the integrity of the floodplain soil community; provide input to wildlife exposure models	PEST, INOR, DLC	Macroinvertebrate tissue chemistry; lipid analysis; floodplain soil chemistry; residue effects threshold values	x	x	x	x		Medium - High	Derived trophic transfer factors used to extrapolate effects to other floodplain habitats; additional soil chemistry necessary to correlate with tissue chemisty

Table 5-1

Data Matrix For Assessment Endpoint #1
Protection and Maintenance of Aquatic and Floodplain Invertebrate Communities

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
6a. Aquatic macroinvertebrate community structure/function	Effect	Identify spatial extent of risk associated with groundwater discharge and non dioxin-like COCs in lotic environments; endpoint integrates exposures from chemical, physical (habitat) and nutrient stressors	VOCs, SVOCs, PEST, INOR, nutrients	Trophic transfer factors (literature and site-derived); sediment chemistry; residue effects threshold values	x	x	x			Medium - High	Assessment areas limited to lotic portions of river in vicinity of site, below Allendale Dam; available RIDEM data collected in more urbanized reach of river downstream of study area
6b. Emerging aquatic macroinvertebrate productivity	Effect	Identify potential forage base reduction; provides direct linkage to swallow foraging/nesting behavior data (see AE # 5)	PEST, INOR	Ennumeration of species and relative abundances of emerging adult insects	x	x	x	x		Medium - High	Study supports AE 5.2a; emerging insects to be collected following completion of swallow study
7. Floodplain macroinvertebrate community integrity	Effect	Identify spatial extent of community level effects; identify potential forage based reduction	SVOCs, PEST, INOR	Ennumeration of species and relative abundances of floodplain invertebrates	x	x	x	x		Medium - High	

Notes:
1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs); Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-2

Data Matrix For Assessment Endpoint #2
Protection and Maintenance of Demersal, Omnivorous Fish Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Fish population surveys of ecological integrity	Effects	Provide measure of population-level effects that integrates across contaminants and exposure pathways	All	Fish length-weight relationships and condition indices; habitat characterization	x	x	x	x		Low	Stratified sampling necessary; habitat characterization critical; evaluate potential effect of non-site related stressors including nutrient enrichment
	"	"	PAHs, DLCs	Percent gross lesions in individual fish (e.g., cranial-facial deformities in YOY larvae)	x	x	x	x		Medium	Data obtained from both IBI (adult) and ichthyoplankton studies
	"	"	All	Demographic structure analysis of dominant species; fish scales collected for age analysis	x	x	x	x		Low	Identify representative demersal, omnivorous fish species
	"	"	All	Species richness and relative abundance in ichthyoplankton	x	x	x	x		Low - Medium	Evaluate existing survey information (RIDFW) with particular focus on sensitive species that should be present

Table 5-2

Data Matrix For Assessment Endpoint #2
Protection and Maintenance of Demersal, Omnivorous Fish Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
2a. Comparison of measured concentrations or toxic equivalencies in fish tissue to literature derived CBRs	Exposure/Effects	Provide input data for wildlife exposure models; identify spatial extent of exposure to sediment COCs; identify primary ELS stressors; contaminant bioaccumulation model calibration	PBTs	Sediment chemistry (including TOC); fish tissue chemistry (including lipid fraction); residue effects threshold values	x	x	x	x		High	Identify representative demersal, omnivorous fish species; supports ELS study (AE 2.3)
2b. Comparison of modeled concentrations or toxic equivalencies in eggs and fish tissue to literature derived CBRs	Exposure/Effects	"	PBTs	Trophic transfer factors (literature and site-derived); sediment chemistry; residue effects threshold values	x	x	x	x	x	Low - Medium	Corroborate site-specific results
3. Partial life cycle laboratory water exposure of fish eggs dosed with synthetic mixture emulating DLC composition of AP fish tissue	Exposure/Effects	Provide direct link between ELS effects and fish tissue COCs; compliments Measure #4 for PRG development	DLCs	Hatchability, fry survival, growth, and presence of development abnormalities in exposed fish; egg tissue chemistry to measure dose	x	x	x	x		High	Candidate species is brown bullhead which is known to occur within watershed but apparently absent from study reach (channel catfish is alternate species); results extrapolated to lower reach

Notes:

1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs);

Table 5-2

Data Matrix For Assessment Endpoint #2
Protection and Maintenance of Demersal, Omnivorous Fish Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**

Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-3

Data Matrix For Assessment Endpoint #3
Protection and Maintenance of Pelagic, Piscivorous or Semi-Piscivorous Fish Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Fish population surveys of ecological integrity	Effects	Provide measure of population-level effects that integrates across contaminants and exposure pathways	All	Fish length-weight relationships and condition indices; habitat characterization	x	x	x	x		Low	Stratified sampling necessary; habitat characterization critical; evaluate potential effect of non-site related stressors including nutrient enrichment
	"	"	PAHs, DLCs	Percent gross lesions in individual fish (e.g., cranial-facial deformities in YOY larvae)	x	x	x	x		Medium	Data obtained from both IBI (adult) and ichthyoplankton studies
	"	"	All	Demographic structure analysis of dominant species; fish scales collected for age analysis	x	x	x	x		Low	Identify representative demersal, omnivorous fish species
	"	"	All	Species richness and relative abundance in ichthyoplankton	x	x	x	x		Low - Medium	Evaluate existing survey information (RIDFW) with particular focus on sensitive species that should be present

Table 5-3

Data Matrix For Assessment Endpoint #3
Protection and Maintenance of Pelagic, Piscivorous or Semi-Piscivorous Fish Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
2a. Comparison of measured concentrations or toxic equivalencies in fish tissue to literature derived CBRs	Exposure/Effects	Provide input data for wildlife exposure models; identify spatial extent of exposure to sediment COCs; identify primary ELS stressors; contaminant bioaccumulation model calibration	PBTs	Representative sediment exposure point concentrations (including TOC); fish tissue chemistry (including lipid fraction); residue effects threshold values	x	x	x	x		High	Identify representative omnivorous, piscivorous fish species; supports ELS study
2b. Comparison of modeled concentrations or toxic equivalencies in eggs and fish tissue to literature derived CBRs	Exposure/Effects	"	PBTs	Trophic transfer factors (literature and site-derived); sediment chemistry; residue effects threshold values	x	x	x	x	x	Low - Medium	Corroborate site-specific results

Notes:
1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs); Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-4

Data Matrix For Assessment Endpoint #4
Protection and Maintenance of Piscivorous Mammal and Bird Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Comparison of estimated ingestion doses in piscivorous wildlife with TRVs and toxicity equivalencies	Exposure/Effect	Evaluate potential food chain risks to piscivorous wildlife based on assumptions of exposure and effects	All	Food chain exposure models; sediment chemistry; site-specific prey tissue chemistry; TRVs	x	x	x	x	x	Medium	Modeled species include river otter, belted kingfisher, great blue heron
2. Comparison of estimated piscivorous wildlife residues with CBRs	Exposure/Effect	Evaluate potential effects to piscivorous wildlife based on estimated tissue residues	PBTs	Literature derived trophic transfer factors to estimate tissue residues; sediment chemistry; fish and other site-specific tissue data (see AEs #1 through 3)	x	x	x	x	x	Medium	Limited uptake data available for belted kingfisher; estimates will be primarily based on extrapolations from regression models
3. Survey of piscivorous wildlife population integrity	Exposure	Provide coarse-grained measure of population-level exposure that integrates across contaminants and exposure pathways	All	Field observational data regarding foraging and breeding activities of piscivorous wildlife; habitat characterization	x	x	x	x		Low	

Notes:

1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs); Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-5

Data Matrix For Assessment Endpoint #5
Protection and Maintenance of Insectivorous Wildlife Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Comparison of ingestion doses in insectivorous wildlife with TRVs and toxic equivalencies	Exposure/Effect	Evaluate potential food chain risks to insectivorous wildlife based on assumptions of exposure and effects	All	Food chain exposure models; sediment exposure point concentrations (including TOC)	x	x	x	x	x	Medium	Modeled species include short-tailed shrew, little brown bat, American woodcock, and tree swallow
2a. Comparison of measured insectivorous wildlife tissue and/or egg residues with CBR data	Exposure/Effect	Evaluate potential effects to insectivorous wildlife based on measured and estimated tissue residues	PBTs	Tree swallow tissue chemistry and literature-derived trophic transfer factors; emergent insect tissue chemistry; sediment chemistry; residue effects threshold values	x		x	x		High	Relate swallow stomach content information to emergent insect abundances and tissue data
2b. Comparison of estimated insectivorous wildlife tissue and/or egg residues with CBR data	Exposure/Effect	Evaluate potential effects to insectivorous wildlife based on estimated tissue residues	PBTs	Literature-derived trophic transfer factors; sediment chemistry; residue effects threshold values	x	x	x	x	x	Medium	Limited uptake data available for woodcock, shrew, and bat; estimates will be primarily based on extrapolations from regression models
3. Measurement of reproductive effects in local tree swallow populations	Effect	Provide measure of population-level effects that integrates across contaminants and exposure pathways	PBTs	Field observations, hatching success, reproduction data; habitat characterization	x		x	x		High	Extrapolate results to other suitable habitat within study area

Table 5-5

Data Matrix For Assessment Endpoint #5
Protection and Maintenance of Insectivorous Wildlife Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
4. Survey of insectivorous wildlife population integrity	Exposure	Provide coarse-grained measure of population-level exposure that integrates across contaminants and exposure pathways	All	Field observational data regarding foraging and breeding activities of insectivorous wildlife; habitat characterization	x	x	x	x	x	Low	
5. Survey of calling amphibians	Effect	Provide coarse-grained measure of population-level exposure that integrates across contaminants and exposure pathways; determine presence of frogs for potential tissue sampling	All	Frog chorus survey during breeding season	x	x	x	x		Low	Survey should be conducted following first warm rain (likely mid April)

Notes:

1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs); Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-6

Data Matrix for Assessment Endpoint #6
Protection and Maintanence of Omnivorous Mammal and Bird Populations

Centredale Manor Restoration Site
North Providence, Rhode Island

					Sampling Areas[2]						
Measures of Effect	**Measurement Category**	**Objective**	**COCs[1]**	**Data Requirements**	**UR**	**BK**	**AP**	**LP**	**DR**	**Inference Weight**	**Notes**
1. Comparison of ingestion doses in omnivorous wildlife with TRVs and toxic equivalencies	Exposure/Effect	Evaluate potential food chain risks to omnivorous wildlife based on assumptions of exposure and effects	All	Food chain exposure models; sediment exposure point concentrations (including TOC)	x	x	x	x	x	Medium	Modeled species include racoon and mallard
2. Comparison of measured or estimated omnivorous wildlife tissue and/or egg residues with CBR data	Exposure/Effect	Evaluate potential effects to omnivorous wildlife based on measured or estimated tissue residues	PBTs	Literature derived trophic transfer factors to estimate tissue residues; sediment chemistry; fish and other site-specific tissue data (see AE #1)	x	x	x	x	x	Low - Medium	Limited uptake data available for the model receptors; estimates will be primarily based on extrapolations from regression models
3. Survey of omnivorous wildlife population integrity	Exposure	Provide coarse-grained measure of population-level exposure that integrates across contaminants and exposure pathways	All	Field observational data regarding foraging and breeding activities of omnivorous wildlife; habitat characterization	x	x	x	x		Low	

Notes:

1. The primary COCs that will be evaluated for each measure of effect are identified; VOCs - volatile organic compounds; SVOCs - semi-volatile organic compounds; PAHs - polycyclic aromatic hydrocarbons; PEST - pesticides; INOR - inorganics; DLC - dioxin-like compounds (including 12 WHO PCB congeners, dioxin/furans, HCX); PBTs - persistent biological toxicants.
2. Sampling areas include upriver (UR), background (BK), Allendale Pond (AP), Lymansville Pond (LP), and downriver (DR).
3. Acronyms: Early Life Stage (ELS); Preliminary Remediation Goal (PRG); Contaminant of Concern (COC); Critical Body Residues (CBRs); Total Organic Carbon (TOC); Assessment Endpoint (AE).

Table 5-7
Summary of Receptors, Evaluated Exposure Pathways, and Measures of Exposure and Effect

Centredale Manor Restoration Site
North Providence, Rhode Island

			Complete Exposure Pathways [b]				Measures of Exposure and Effect						
							Site-specific Data [c]				Literature-based Comparisons		
Assessment Endpoint [a]	Receptor Group	Example Taxa	Direct Contact with Abiotic Media	Incidental Ingestion of Soil/ Sediment	Water Consumption	Prey Ingestion	Analytical Chemistry - Abiotic Media	Analytical Chemistry - Biota	Population/ Community Field Studies	Toxicological Bioassays	Benchmark [d]	CBR [e]	TRD [f]
1	Invertebrates												
	aquatic	crayfish, dragonflies	✓	✓	*	*	✓	✓	✓	✓	✓	✓	
	terrestrial	earthworms, sowbugs	✓	✓		*	✓	✓	✓		✓	✓	
2	Demersal Fish	catfish, eel	✓	*	*	*	✓	✓	✓	✓		✓	
3	Pelagic Fish	large mouth bass, sunfish	✓	*	*	*	✓	✓	✓			✓	✓
4	Piscivorous Wildlife	otter, kingfisher, heron	*	✓	✓	✓	✓					✓	✓
5	Insectivorous Wildlife	swallow, bat	*	✓	✓	✓	✓	✓	✓			✓	✓
6	Omnivorous Wildlife	raccoon, mallard	*	✓	✓	✓	✓					✓	✓

Notes:

a. Assessment Endpoints follow the summaries provided in Tables 5-1 through 5-6.
b. Exposure Pathways are summarized in the Site Conceptual Model presented in Figure 4; checks indicate pathways that will be quantitatively evaluated in the BERA; asterisks represent complete pathways that will be qualitatively evaluated.
c. Site-specific data collection activities to support the BERA are discussed in Section 3; details of all field activites will be provided in the SAP.
d. Toxicity benchmarks for abiotic media are described in the text.
e. CBR - Critical Body Residue; body residues for piscivorous and omnivorous wildlife will be estimated for the CBR evaluation.
f. TRD - Toxicity Reference Dose

ATTACHMENT A
FISH SAMPLING PROCEDURES

ATTACHMENT A
FISH SAMPLING PROCEDURES

CENTREDALE MANOR PROJECT SUPERFUND SITE
NORTH PROVIDENCE, RHODE ISLAND

Introduction

To evaluate the uptake potential of dioxin-like compounds and other persistent biological toxicant COPCs in fish tissue, fish sampling activities will be completed in selected areas of the Woonasquatucket River and associated lakes downgradient of the Centredale Manor Site. Sampling and analysis activities will be completed according to *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis*, EPA 823-R-95-007 (USEPA, 1995). Sample collection will be accomplished using a variety of techniques, including electrofishing and netting. Fish samples will be submitted to a chemical laboratory for whole body, fillet, and egg analysis, and the data will be used to evaluate potential risks to both human health and ecological receptors. Samples will be collected in the summer of 2001 to evaluate typical exposures to piscivorous wildlife from ingesting pre-spawn female fish, and for persons catching and eating male and female fish throughout the summer. Harding ESE anticipates working in collaboration with a subcontractor during sampling activities.

Tasks associated with the investigation include the following:

- acquisition of three target species from three trophic levels,
- division of fish into age/size groups for size distribution comparison,
- selection of samples from an older age/larger size group for each trophic level,
- identification of stressors (i.e., parasites, tears, or lesions), and
- hard freezing and preparing samples for packing.

Preliminary Activities

Activities to be conducted prior to the commencement of field work including the following:

- select candidate fish species based on a qualitative creel survey;
- confirm the sampling locations;
- mobilize equipment and supplies; and
- receive debriefing on site history, health and safety requirements, and field procedures.

Electrofish/Net Investigation

Based on a review of contaminant distribution and site maps, ten sample locations will be identified in the following four exposure areas:

- an upgradient area (i.e., Greystone Mill Pond);
- a reference area (i.e., the impounded pond along Assapumpset Brook);
- Allendale Mill Pond; and
- Lymansville Pond.

The exact location of these sampling points will be determined in the field, based on habitat suitability and preferred foraging and shelter areas. Fish will also be collected from locations where public fishing access is possible. During the survey, water-level data and water quality information (e.g., temperature, pH, specific conductance, turbidity, and dissolved oxygen) will be obtained at each sample location.

Fish will be collected by electroshock equipment and by nets (i.e., gill nets, hoop nets, haul seines, trot lines, etc.), as appropriate. Electroshock equipment are preferable for catching smaller, pelagic species in shallow water, whereas nets or trot lines are preferable for catching demersal species and larger fish, particularly in deep water. Ichthyoplankton will be collected using Bongo nets or similar sampling apparati.

Electrofishing can be conducted either from shore or from a boat in freshwater with a normal conductivity between 100 to 500 micromhos/cm (Reynolds, 1983). Electrofishing in lakes will occur from an aluminum boat with boom-mounted electrodes and a live well. Captured fish will be kept alive either on-shore or in the electrofishing boat. Fish selected for samples will be identified to species, and the number of individuals of each species collected will be recorded in the field logbook. Fish not selected for laboratory sample preparation will be released.

A subcontractor that will provide electroshocking equipment, nets, and a boat, and complete all fishing activities. Harding ESE will oversee field activities and maintain sample chain-of-custody. Both the subcontractor and Harding ESE will maintain documentation of all field activities, including number of each type of species caught, number of fish included in each sample, length, weight, and gross morphological abnormalities.

Species and volume requirements of this investigation are:

- Collect representative species from each of the trophic levels of ecological concern, including demersal, omnivorous fish (e.g., catfish), and pelagic piscivorous or semi-piscivorous fish (e.g., largemouth bass (*Micropterus salmoides*) or sunfish (*Lepomis* sp.). Sport fish (such as bass) and other species that may be consumed by local residents, such as the American eel (*Anguilla rostrata*), will also be targeted for evaluating human health risks. If yields of these species of fish are low, then other species of fish representing the same trophic levels may be sampled instead. Enough volume will be collected to allow for whole body and fillet only analysis.
- Collect adequate fish of either gender within an older age/larger size group to yield enough volume of tissue for analytical requirements. Volume requirements will likely be 100 to 200 grams per sample. Samples designated as duplicates or MS/MSDs will need to have 300 or more grams of tissue. To achieve these volume requirements, fish of similar size and age may need to be composited in the field to meet the analytical requirements.

Once the adequate number of fish and/or sample volumes have been collected and allocated, whole-fish samples will be double-bagged and labelled. Sample labels will be affixed to the sample package and taped with clear plastic packaging tape. Sample labels will be attached to each sample submitted for laboratory analysis. Project number, Sample Identification Number, date and time of collection, and name(s) of field personnel are recorded on each label. Samples will be packed in dry ice in shipping containers, and then shipped to the laboratory for sample processing (i.e., filleting and scaling for samples intended for the human health evaluation) and analysis. Composited fish tissue will be analyzed for dioxins/furans, pesticides/PCBs, metals, and percent lipids.

ATTACHMENT B
BENTHIC INVERTEBRATE COMMUNITY SURVEY AND HABITAT ASSESSMENT

ATTACHMENT B
BENTHIC INVERTEBRATE COMMUNITY SURVEY AND HABITAT ASSESSMENT

CENTREDALE MANOR PROJECT SUPERFUND SITE NORTH PROVIDENCE, RHODE ISLAND

Introduction

A portion of the Woonasquatucket River reach adjacent to the Site receives groundwater discharge containing Site-related VOCs. Because this may represent a complete exposure pathway for aquatic organisms, a qualitative survey of the diversity, abundance, and relative biomass of the benthic and epibenthic macroinvertebrate communities will be conducted to determine whether groundwater discharge is adversely affecting the macroinvertebrate community. In addition, a qualitative habitat assessment will also be completed to evaluate the relative impairment of the portions of the Woonasquatucket River downstream of the Site. These surveys will be conducted following the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition* (Barbour, 1999), followed by a quantitative study that will assess the potential for ecological impact to the macroinvertebrate community.

The areas that will be sampled as part of these surveys include:

- The groundwater discharge area in the lotic environment between the Site and Allendale Mill Pond; and
- The lotic recovery area between Allendale Mill Pond and Lymansville Pond.

The surveys will also encompass an upgradient area and a reference area, including:

- The lotic portion of the Woonasquatucket River between Greystone Mill Pond and the Site; and
- The lotic portion of Assupumpset Brook downstream of the pond.

Scores from downstream areas will be compared with the upstream and reference areas to determined the relative level of impairment.

Benthic Invertebrate Community Survey

Macroinvertebrate infauna associated with microhabitats within these reaches will be identified, and the presence or absence of characteristic taxonomic groups will be noted. The variety of microhabitats found in rivers and streams support different components of the aquatic community based on feeding or refuge preferences. These microhabitats, as described in Plafkin et al. (1989) and by the Mid-Atlantic Coastal Stream (MACS) Workgroup (MACS Workgroup, 1997), may include:

- riffles (areas with generally the most diverse community of macroinvertebrates, where a fast current travels over a cobble and gravel substrate),
- runs (straight areas where a slow current travels over a cobble and gravel substrate),
- bends (ideal in streams lacking riffles where the cutting action in a bend provides added habitat),
- pools (areas that provide living space for aquatic life, particularly fish, under drought conditions),
- depositional areas (areas where there is an accumulation of plant debris [e.g., leaves, needles, twigs, bark]),
- cobble/gravel bottom areas,
- submerged snags (which increases the available surface area of a stream or river, creates pools, traps organic matter, and provides a stable substrate for the macroinvertebrate community),
- vegetated banks (providing a source of organic enrichment), and
- submerged macrophytes (important for supporting macroinvertebrate communities in open channels receiving direct sunlight).

A variety of these microhabitats or features is ideal for supporting a diverse macroinvertebrate and fish community. Cummings and Wilsbach (1985) have broadly-defined four functional feeding groups for classifying stream macroinvertebrates, on which the sampling methods for rapid bioassessment protocol (RBP) (Barbour, 1999) are based. The four functional feeding groups include:

- Shredders. Shredders eat coarse particulate organic matter (i.e., >1 mm), and are likely to be found along or under stream banks and submerged snags, and in depositional areas where there is a collection of organic material.
- Collectors. Collectors feed on fine particulate organic matter (i.e., <1 mm) by filtering particulates from the water or by gathering organic matter from sediment. Filtering collectors may be found embedded in the substrate of riffles and/or runs, and gathering collectors may be found in quieter water regimes, such as depositional areas or pools.
- Scrapers. Scrapers feed on the periphyton (i.e., algae and diatoms) that attach to rock and wood surfaces, and may be found on the undersides of gravel or cobble, or on large branches and logs.
- Predators. Predators have specialized body parts and behaviors for feeding, and are found in a variety of habitats in search of prey, but are often found in submerged aquatic vegetation that provides suitable cover for a variety of macroinvertebrates.

Dip nets will be used under snags and riverbanks, in pools, and in submerged aquatic vegetation, as proposed by the multi-habitat method (Barbour, 1999). If appropriate riffle habitat is available, a 1 m^2 kick net will be used following the single habitat approach. In addition, cobbles and large gravel will be overturned to search for infauna that attaches to the substrate. To provide a relative measure of the diversity and abundance of fish and large macroinvertebrates (e.g., crayfish) within the study area, minnow traps and cast nets may be employed. Incidental observations of other wildlife (e.g., fish, amphibians, and

piscivorous birds and mammals) occurring in the vicinity of, or using the resources of, the Woonasquatucket River will also be noted.

Field data sheets provided in Barbour (1999) will be completed to document the habitat types, equipment used, and field observations of macroinvertebrates within a river reach.

Benthic community metrics will be calculated following the Invertebrate Community Index (ICI) (Barbour et al., 1999). These metrics include measures of richness, composition, tolerance/intolerance, feeding, and habitat. One concern may be the confounding effect of organic enrichment associated with VOCs sorbed to fine particulate matter. This may result in the decreased presence of filter collectors, thereby rendering some metrics (e.g., the scraper to filter collector ratio) less ideal as indicators of organic enrichment (Plafkin et al., 1989).

Habitat Assessment

In conjunction with the benthic community survey, the physical in-stream and bank habitat will be characterized in the same portions of Woonasquatucket River downgradient of the Centredale Manor Site consistent with the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition* (Barbour, 1999). Information concerning riverbed substrate, flow rates, water depth, river width, presence and types of macrophytes, local land use, and other features (e.g., riffle/run habitat) will be obtained during a complete transverse of the study area. The adjacent floodplain and upland plant communities will be described floristically as they provide habitat for species that may utilize the river as well as representing a primary source of exogenous nutrients to the river system. Tributaries and manmade culverts, whose discharge may influence downriver water quality, will also be noted. Water quality information, including: pH, specific conductance, turbidity, dissolved oxygen, and temperature will be obtained at each microhabitat encountered along the river transverse. This information will be used to assess the variability of environmental conditions throughout the study area that may influence the distribution and abundance of aquatic receptors.

Field data sheets provided in Barbour (1999) will be completed to document the physical characterization/water quality and habitat assessment.

ATTACHMENT C
DEVELOPMENT OF TOXICITY EQUIVALENT QUOTIENTS (TEQ) AND BENCHMARKS FOR DIOXINS, FURANS, AND COPLANAR PCB CONGENERS

DEVELOPMENT OF TOXICITY EQUIVALENT CONCENTRATIONS AND BENCHMARKS FOR DIOXINS, FURANS, AND COPLANAR PCB CONGENERS

CENTREDALE MANOR PROJECT SUPERFUND SITE NORTH PROVIDENCE, RHODE ISLAND

Due to the limited toxicological data available for many individual dioxin, furan, and coplanar PCB congeners and to simplify the risk assessment process, a methodology has been developed that quantifies the toxicities of various dioxin, furan, and coplanar PCB congeners relative to the toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) (Van den Berg et al., 1998). TCDD is widely accepted to be the most toxicological significant chemical among these groups of analytes, all of whose toxicological properties are assumed to be regulated by their individual abilities to bind to the cytosolic Ah receptor. Since 2,3,7,8-TCDD has the greatest affinity for the AhR, it is arbitrarily assigned a Toxicity Equivalent Factor (TEF) of 1. Other congeners are assigned a TCDD TEF relative to 2,3,7,8-TCDD based on experimental evidence concerning their relative binding potential to the Ah receptor. The potency of the congener is then estimated by multiplying the measured media concentration by the TEF for the particular congener to yield a toxic equivalent concentration. Finally, a toxic equivalent concentration for the entire sample can be determined by summing the calculated toxic equivalent concentrations for each Ah receptor-binding congener; the resulting concentration is a measure of the potency of the entire mixture represented in terms of 2,3,7,8-TCDD, and is expressed as a TCDD-equivalent concentration. This methodology assumes that the combined effects of the different congeners are dose or concentration additive, and this has been generally supported by results of many studies. This approach fails to consider the toxicological significance of effects that are not mediated by the Ah receptor (e.g., neurotoxicity and various hormonal effects). However, current consensus is that the TEF approach is the best methodology for assessing the impacts associated with exposure to dioxin-like compounds (Van den Berg et al., 1998).

Species specific factors such as uptake, disposition, and metabolism of TCDD, as well as interspecies differences in concentration, tissue distribution, and ligand affinity of the Ah receptor all likely contribute to the relative sensitivities of different organisms to TCDD (USEPA, 1993). Nonetheless, the relative affinity of 2,3,7,8-substituted dioxins and furans, and coplanar PCBs appears to correlate well with the relative toxicity of these compounds to different species. The absence of the Ah receptor in invertebrates and plant species is consistent with the lack of apparent toxicity of these compounds to these organisms. Recent information suggests that there are enough differences in the binding potential of dioxin-like compounds to warrant developing separate TEFs for mammals, birds, and fish (Van den Berg, 1998).

Table D-1 presents the TEFs developed by the World Health Organization (WHO). Van den Berg et al. (1998) summarizes the basis for developing the WHO TEFs and reviews the specific effects on which they are based. WHO recommends using the mammal-derived TEFs for estimating toxic equivalent concentrations for both humans and wildlife species. While most pertinent for assessing the relative potency of dioxin-like compounds in biological tissues, the TEF approach has also been employed to estimate the relative concern associated with different samples of abiotic media such as sediment or surface water. TEFs were applied to the detected congener concentrations detected in sediment, surface water, and floodplain soil in this baseline

ERA, however, the influence of various physicochemical processes introduce considerable uncertainties in inferring toxicological potencies when applied to these environmental media. TEFs expressed as less than ("<") were conservatively estimated using the provided value.

For the baseline HHRA, the human/mammal TEFs were used to develop toxic equivalent concentrations for individual congeners.

TABLE C-1
TOXICITY EQUIVALENCY FACTORS (TEFs) AND BIOTA SEDIMENT ACCUMULATION FACTORS (BSAFs) FOR HUMANS, WILDLIFE, FISH, AND BIRDS

CENTREDALE MANOR PROJECT SUPERFUND SITE
NORTH PROVIDENCE, RHODE ISLAND

Congener[b]	TEF[a]			BSAF[c]
	Humans/ Mammals	Fish	Birds	
2,3,7,8-TCDD	1	1	1	0.06
1,2,3,7,8-PeCDD	1	1	1	<0.05
1,2,3,4,7,8-HxCDD	0.1	0.5	0.05	<0.02
1,2,3,6,7,8-HxCDD	0.1	0.01	0.01	<0.01
1,2,3,7,8,9-HxCDD	0.1	0.01	0.1	<0.01
1,2,3,4,6,7,8-HpCDD	0.01	0.001	<0.01	<0.002
OCDD	0.0001	<0.0001	0.0001	<0.001
2,3,7,8-TCDF	0.1	0.05	1	0.07
1,2,3,7,8-PeCDF	0.05	0.05	0.1	0.02
2,3,4,7,8-PeCDF	0.5	0.5	1	0.11
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1	<0.03[d]
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1	<0.02
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1	<0.03
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1	<0.03
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01	<0.0002
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01	<0.01
OCDF	0.0001	0.0001	0.0001	<0.0003
3,4,4',5-TCB	0.0001	0.0005	0.1	NA
3,3',4,4'-TCB	0.0001	0.0001	0.05	NA
3,3',4,4',5-PeCB	0.1	0.005	0.1	NA
3,3',4,4',5,5'-HxCB	0.01	0.00005	0.001	NA
2,3,3',4,4'-PeCB	0.0001	<0.000005	0.0001	NA
2,3,4,4',5-PeCB	0.0005	<0.000005	0.0001	NA
2,3',4,4',5-PeCB	0.0001	<0.000005	0.00001	NA
2',3,4,4',5-PeCB	0.0001	<0.000005	0.00001	NA
2,3,3',4,4',5-HxCB	0.0005	<0.000005	0.0001	NA
2,3,3',4,4',5'-HxCB	0.0005	<0.000005	0.0001	NA
2,3',4,4',5,5'-HxCB	0.00001	<0.000005	0.00001	NA
2,3,3',4,4',5,5'-HpCB	0.0001	<0.000005	0.00001	NA

Notes:

a. Toxicity Equivalency Factors (TEFs) derived by the World Health Organization and presented in Van den Berg *et al.*, 1998.
b. Abbreviations: CDD – chlorinated dibenzodioxin, CDF – chlorinated dibenzofuran, CB – chlorinated biphenyls
c. Biota Sediment Accumulation Factors (BSAFs) presented in USEPA, 1993. NA – BSAF not available. Additional BSAFs presented in USEPA, 1998 will also be utilized.
d. Value presented was derived for the surrogate congener 1,2,3,7,8,9-HxCDF.