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2 March 2005

Ms. Jena Sleboda (SRF-5J)
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U.S. Environmental Protection Agency
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U.S. EPA Contract No.: 68-W7-0026
Work Assignment No.: 236-TATA-05FV
Document Control No.: RFW236-2A-ASQP

Subject: Final Ecological Risk Assessment
Manistique Harbor and River Site
Manistique, Michigan

Dear Ms. Sleboda:

Weston Solutions, Inc. (WESTON®) is pleased to submit to the U.S. EPA, three copies of the Final Ecological Risk Assessment, Revision 1 for the Manistique Harbor and River AOC in Manistique, Michigan.

Should you have any questions or require additional information, please feel free to contact us.

Very truly yours,

WESTON SOLUTIONS, INC.

Steven R. Bosko
Site Manager

James M. Burton, P.E.
Program Manager

SRB:JMB/tg
Enclosure
cc: P. Vogtman, U.S. EPA (letter only)

WESTON SOLUTIONS, INC.

MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

ECOLOGICAL RISK ASSESSMENT

REVISION 1 – 2 March 2005

WORK ASSIGNMENT NO. 236-TATA-O5FV

WESTON SOLUTIONS

MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

ECOLOGICAL RISK ASSESSMENT

REVISION 1 – 2 March 2005

WORK ASSIGNMENT NO. 236-TATA-O5FV

Prepared for

U.S. EPA Contract No. 68-W7-0026
U.S. Environmental Protection Agency
77 West Jackson Boulevard
Chicago, Illinois 60604

Revision 1 – 2 March 2005 – Document Control Number RFW236-2A-ASQP

Prepared By: Steven R. Bosko Date: 3/2/05
Steven R. Bosko
Site Manager

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Program Manager

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EXECUTIVE SUMMARY

INTRODUCTION

A baseline ecological risk assessment (ERA) was prepared to evaluate the post-dredging conditions in the Manistique Harbor and River Area of Concern (AOC). The Manistique Harbor and River AOC has been impacted by point and non-point sources of pollution. The harbor and river sediments contained elevated levels of polychlorinated biphenyls (PCBs) primarily from industrial and paper milling operations. Dredging commenced in 1996 and was completed in 2000. Information and data collected during the post-dredging site investigation in September 2004 serves as the basis for this task. The site investigation data, combined with the results of the ERA and the Human Health Risk Assessment, will provide the information needed for development of the overall long-term management strategy for the Manistique Harbor and River.

PROBLEM FORMULATION

The problem formation establishes the goals, breadth, and focus of the baseline ERA. It also establishes assessment endpoints or specific ecological values to be protected. The environmental setting is characterized, the complete exposure pathways are determined, and the assessment and measurement endpoints are selected.

Aquatic habitat in the Manistique Harbor and River site supports a variety of seasonal sport fish including northern pike, yellow perch, channel catfish, smallmouth bass, rock bass, walleye, chinook salmon, coho salmon, pink salmon, brown trout and steelhead. Land habitat in the area is primarily sandy beach, low shrubs, and developed sites, which can be used by shorebirds and gulls. Bald eagles forage along the shoreline in the vicinity of the AOC. Waterfowl habitat is available primarily on the eastern shore of the river near U.S. 2, where the dead end channel creates a marsh. There is little available wildlife habitat elsewhere in the AOC, since the entire site lies within the City of Manistique and the shoreline and nearby areas are relatively developed (Triad Engineering and TerraFirma Environmental, 2002).

Complete exposure pathways include birds and mammals exposed through dietary ingestion of PCBs in sediment that accumulate in the food foraged by the bird or mammal, and any incidental ingestion or direct contact with PCB-contaminated media that occurs through the diet or through foraging or nesting activities. Benthic invertebraes can be significantly exposed through direct contact and dietary ingestion of PCBs in sediment, sediment pore water, and surface water. Fish can be exposed through dietary ingestion of PCB in sediment that accumulate in the food foraged by the fish, and any incidental ingestion or direct contact that occurs through the diet or through foraging. Exposure to PCBs dissolved in the water column can also occur through gills, dermis, and food ingestion.

Assessment and measurement endpoints primarily focus on the potential "link" between wildlife and food sources from within the Manistique Harbor and River and secondarily on direct contact exposures for organisms living in or on the Manistique Harbor and River. The assessment objective and the measurement endpoint (as measures of exposure) being used are summarized below:

- Protection of benthic organisms - Comparison of sediment concentrations with toxicity-based benchmark values.
- Protection of feral fish population - Comparison of tissue concentrations with residue-effect concentrations.
- Protection of populations of piscivorus birds - Food-chain modeling and comparison to TRVs for the bald eagle.
- Protection of populations of piscivorus mammals - Food-chain modeling and comparison with TRVs for the mink.

The target receptors were selected based on the concept that it is neither feasible nor cost-effective to measure constituent effects on all species inhabiting the aquatic and terrestrial habitat associated with the Manistique Harbor and River site. In addition, these target receptors (i.e., benthic organisms, feral fish, benthic organism, mink and bald eagle) were evaluated in the pre-dredging qualitative ERA (Terra Inc., 1994).

SITE INVESTIGATION

The September 2004 sampling activities focused on the collection of physical, chemical, and biological samples. The constituent of potential concern at this site is PCBs. The environmental media sampled for PCB analysis included sediment, surface water, resident fish, caged fish, and semi-permeable membrane devices (SPMDs). The ERA focuses on those media that ecological receptors can be exposed to - sediment and wholebody fish. Surface water is not evaluated in the ERA because PCBs were not detected in this medium.

CHARACTERIZATION OF EXPOSURE

For target receptors or communities that are exposed directly to the media in which they live (such as benthic invertebrate and fish), uptake is expressed in terms of measured concentrations of constituents in the media in which they reside (for example the concentration of constituents in sediment are used to directly estimate the intake received by benthic organisms) or residual contaminant concentrations in tissue. For target receptors that are exposed through the food chain, daily exposure intake models were developed which express exposure in terms of constituent intake per kilogram of body weight per day (mg/kg-day). The ingestion of fish and incidental ingestion of sediment represent the primary routes of exposure to the bald eagle and the mink. In this ERA, trophic level 3 and trophic level 4 fish tissue has been assumed to compose 100 percent of a receptor's diet, and the receptors are assumed to obtain 100 percent of their diet from the harbor and river.

CHARACTERIZATION OF EFFECTS

Ecological toxicity reference values (TRVs) for PCBs and for the individual Aroclors were obtained from the literature. TRVs based on media concentrations are used for benthic organisms and fish and TRVs based on dose are used for bird and mammal receptors. TRVs were obtained from the sources listed below.

- Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS) on-line database (http://risk.lsd.ornl.gov/rap_hp.shtml).
- U.S. EPA Region 9 Biological Technical Assessment Group (BTAG) (http://www.dtsc.ca.gov/ScienceTechnology/eco.html#BTAG).
- Final Baseline Human Health and Ecological Risk Assessment. Lower Fox River and Green Bay, Wisconsin. Remedial Investigation and Feasibility Study (The Retec Group, 2002).
- U.S. Army Corps of Engineers/U.S. Environmental Protection Agency Environmental Residue-Effects Database (ERED). (http://www.wes.army.mil/el/ered)

Multiple benchmarks are used to evaluate effects on benthic organisms. The use of multiple benchmarks provides an indication of the likelihood and nature of effects. For example, exceedance of only one conservatively estimated benchmark may provide weak evidence of real effects, whereas exceedance of multiple benchmarks of varying conservatism may provide strong evidence of real effects (Jones et al., 1996).

Exposure of fish to potentially deleterious concentrations of PCBs is evaluated based on tissue residues. The U.S. Army Corps of Engineers/U.S. Environmental Protection Agency (2004) Environmental Residue-Effects Database (ERED) was consulted for toxicity data for fish. The ERED contains information on the broad range of biological effects caused by the presence of a particular contaminant in the tissue of an organism. Both no observed effect dose (NOED) and lowest observed effect dose (LOED) concentrations were selected as no effect and the effect TRVs for fish exposure based on the similarity of the test species and the target species for this site.

There are no U.S. EPA-established, acceptable daily doses for ecological receptors; therefore, dose-based TRVs were developed from the available scientific literature. Both no effect TRVs, consistent with a chronic no-effect level, and effect TRVs, consistent with a low effect level, are used to evaluate effects to the bald eagle and mink. Allometric modeling from Sample and Arenal (1999) was used for interspecies extrapolations when the test species is different from the wildlife or target receptor species.

RISK CHARACTERIZATION

The hazard quotient (HQ) method is used as an indicator of the risks posed to surrogate ecological receptors from exposure to site-related contaminants (U.S. EPA, 1996c). The hazard quotient compares exposure values to TRVs, and can be expressed as the ratio of a potential exposure level to the TRV.

To assess the potential for adverse effects on benthic organisms from exposure to potentially toxic sediment, the range of detected sediment concentrations in the Manistique Harbor and River were compared to sediment screening benchmarks. The average concentration of PCBs did not exceed the highest benchmark, but average concentration did exceed the threshold concentrations. While these results show a potential for adverse impacts to benthic organisms from sediment exposure, these risks may be localized at particular "hotspots", rather than distributed throughout the harbor and river. Note that no PCBs were detected in the Inner Harbor, and the highest detected concentration was measured in the Outer Harbor.

Exposure of fish to potentially deleterious concentrations of PCBs is evaluated based a comparison of tissue residues to residue effects concentrations. The mean and 95% UCL concentration of total PCBs in the whole body fish tissue for the target species collected from the Manistique Harbor and River were compared to tissue NOEDs and LOEDs for similar fish. For the bottomdweller (i.e., omnivorous) fish species, the HQs range from 0.017 to 6.9, indicating potential risk to these species.

The HQ exceeded one for the sucker species but not for the channel catfish. The HQs based on the LOED and the 95% UCL tissue concentration did not exceed one for any of the bottomfeeder species. For the predator (i.e., carnivorous) fish species, the HQs range from 0.07 to 0.6. For the predatory fish species, the HQs were less than 1.0 and therefore indicate no risk.

The bald eagle may be exposed to PCBs through ingestion of fish and incidental ingestion of sediment. The HQ based on the no effect TRV was 0.51 for total PCBs and the HQ based on the effect TRV was 0.036 for total PCBs. All HQs for the individual Aroclors were less than 1. These HQs were less than one and therefore indicate no risk to the eagle. For the mink, the HQ based on the no effect TRV was 1.2 for total PCBs and the HQ based on the effect TRV was 0.6 for total PCBs. For Aroclor 1248, the HQ based on the no effect TRV was 1 and the HQ based on the effect TRV was 0.1. The HQs based on the no effect TRV exceeded one for the total PCBs indicating potential risk. However, the HQs based on the effect TRV for total PCBs and for the individual Aroclors were less than 1, suggesting that this potential risk is limited.

Overall, the HQ analysis indicates that exposure to PCBs by piscivorous birds and mammals poses little to no risk to the eagle and the mink. The HQ analysis indicates potentially unacceptable levels of risk to benthic organisms and bottomdwelling species. However, the substrate provided by the harbor and river is not expected to support a thriving benthic community. The highest tissue residue concentrations were measured in bottomdwelling species, which have high lipid contents. The higher the lipid content, the higher the resistance to the toxicant because a higher proportion of the hydrophobic compound is associated with the lipid and is not available to cause toxicity (Meador, 2002). In contrast, lipid levels positively correlate with bioaccumulation and the half-life of absorbed contaminants in receptor species (Geyer et al., 1997). Thus, while receptors with high lipid content will both absorb and retain chemicals to a greater extent, there is potential for increased risk to predators consuming prey with high lipid contents. Since there is a potential for adverse effects on benthic organisms and fish, continued monitoring of sediment and fish tissue is recommended.

SECTION 1
INTRODUCTION

1.1 PURPOSE

The purpose of this document is to present an ecological risk assessment for the post-dredging conditions in the Manistique Harbor and River Area of Concern (AOC). This document was prepared by Weston Solutions, Inc. (WESTON®) under U.S. EPA Region V Work Assignment No. 236-TATA-05FV.

1.2 BACKGROUND

The Manistique Harbor and River Area of Concern (AOC) is located on the Manistique River near the City of Manistique, Schoolcraft County, Michigan (Figures 1-1 and 1-2). The Manistique Harbor and River AOC has been impacted by point and non-point sources of pollution. The harbor and river sediments contained elevated levels of polychlorinated biphenyls (PCBs) primarily from industrial and paper milling operations. Dredging was initiated in 1996 in an area adjacent to the former paper mill. The former paper mill was determined to be a source area for the PCBs. From 1997 through 2000, extensive dredging was performed in the South Bay of Manistique Harbor and in the Manistique River. Dredging was focused on areas containing PCBs above the site action level of 10 parts per million (ppm), with priority given to areas with higher PCB contamination levels. By the end of the 2000 field season, the average levels of PCBs in the sediment were below the U.S. EPA action level of 10 ppm, and the dredging of the site was completed (Lockheed Martin, 2003).

Over a period of years, some fraction of the residual mass of PCBs in the Manistique Harbor and River may migrate into the water column or be buried or mixed into the river and harbor sediments via dynamic sediment processes or bioturbation. With time the harmful effects of these residual sediments (uptake into the water column and increased bioavailability of PCBs) will be reduced. After dredging, new, clean sediments are expected to accumulate more rapidly than current sedimentation rates because of the increased depth of the harbor and channel. This resedimentation (at a rate of approximately 1.5 inches per year) is also expected to reduce the impact of the remaining PCB residuals (Interagency Review Team, *Assessment of Remediation Technologies, Manistique River and Harbor Area of Concern, Final Report*, U.S. EPA 1995a).

1.3 PRE-DREDGING ECOLOGICAL RISK ASSESSMENT

A qualitative ERA was prepared prior to dredging of the Manistique Harbor and River (Terra Inc., 1994). The qualitative ERA evaluated potential impacts of PCBs in sediment on benthic organisms, feral fish, bald eagles, and mink. Average PCB concentrations in sediment fell in "probable effect range" or the "marginally polluted range" for generic sediment screening values for the protection of benthic organisms. Measured water column PCB data was below lethal and subchronic non-lethal endpoints for fish. The report stated that it was difficult to predict with any confidence the adverse impacts that contaminated sediments would have on the local bald eagle population. Based on the bioaccumulation model used in this assessment to estimate fish tissue concentrations, the assessment concluded that risk to the mink can be reduced by lowering the surface sediment concentrations. The ERA determimed that though dredging without capping would result in lowered PCB concentrations, residual concentrations would remain that have the potential for deleterious reproductive effects in mink. In summary, the qualitative ERA determined the potential for adverse effects to ecological receptor organisms under both baseline conditions and after dredging to a 10 ppm level.

1.4 OBJECTIVES

The *Manistique River and Harbor Qualitative Ecological Risk Assessment* (Terra Inc., 1994) identified concentrations of PCBs in sediment at levels that may cause an adverse impact to ecological receptors at the Manistique AOC. This document presents an ERA for the post-dredging conditions. The primary objectives of this ERA are to:

- Evaluate PCB levels in sediment, surface water, and fish tissue after completion of dredging.
- Assess the potential for adverse impact to ecological receptors, focusing on exposures to avian and terrestrial piscivores.
- Develop conclusions and recommendations for additional investigation or no further action, as appropriate, based on the findings from the ERA.

This ERA will also provide information needed for development of the overall long-term management strategy for the Manistique AOC.

1.5 APPROACH

The methodology used to assess the potential ecological risks at the Manistique AOC draws upon guidance set forth in the following documents:

- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (U.S. EPA, 1997).
- *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998).
- *Framework for Ecological Risk Assessment* (U.S. EPA, 1992).

The U.S. EPA's *Framework* document (1992) defines an ERA as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. This document provides the basic process and principles to be used in an ERA, which include problem formulation, analysis (including characterization of exposure and characterization of effects), and risk characterization. The U.S. EPA (1997) has developed an eight-step ERA process for Superfund that is based on this ecological risk assessment framework. The steps are:

Step 1: Screening Level Problem Formulation and Ecological Effects Evaluation
Step 2: Screening Level Preliminary Exposure Estimate and Risk Calculation
Step 3: Baseline Risk Assessment Problem Formulation
Step 4: Study Design and Data Quality Objectives
Step 5: Field Verification of Sampling Design
Step 6: Site Investigation and Analysis of Exposure and Effects
Step 7: Risk Characterization
Step 8: Risk Management

The first two steps in the assessment process are streamlined versions of the complete framework process, and are intended to allow a rapid determination that a site poses nor or negligible risks, or to identify which contaminants and which exposure pathways require further evaluation. Steps 3 through 7 are a more detailed version of the ecological risk assessment framework, and these steps are the followed in this ERA for the Manistique Harbor and River site.

1.6 REPORT ORGANIZATION

The ERA report is organized as follows:

Executive Summary
Section 1 – Introduction
Section 2 – Problem Formulation
Section 3 – Site Investigation
Section 4 – Characterization of Exposure
Section 5 – Characterization of Effects
Section 6 – Risk Characterization and Uncertainty
Section 7 – References

Appendices include the following:

Appendix A – Analytical Data Tables
Appendix B - ERED Summary
Appendix C - Toxicological Profile for PCBs

The tables and figures cited in the text are provided at the end of the section in which they are first referenced.

FIGURES

N

0 500 Feet

Notes:
Orthophoto acquired from USEPA FIELDS.

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Figure 1-1

WESTON

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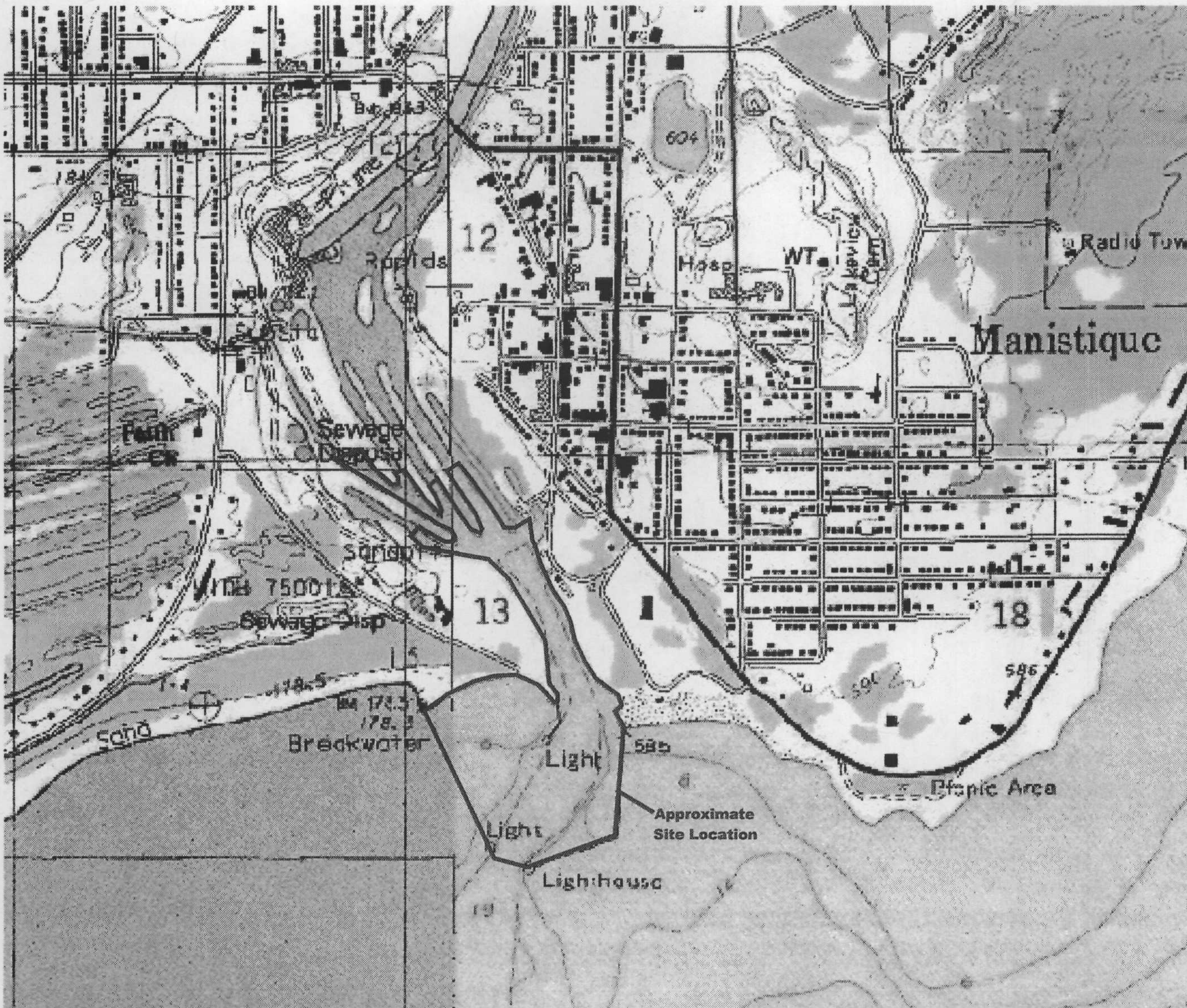
Area Location Map

Manistique Harbor, Michigan



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Notes:
USGS Quad Map: Manistique, MI East and West

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Figure 1-2

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Site Location Map

Manistique Harbor, Michigan

SECTION 2

PROBLEM FORMULATION

In Step 3 of the ERA process, the problem formation establishes the goals, breadth, and focus of the baseline ERA. The problem formulation also establishes assessment endpoints or specific ecological values to be protected. The questions that need to be addressed are defined based on potentially complete exposure pathways and ecological effects. A conceptual model of the site is developed that shows the complete exposure pathways evaluated in the ERA and the relationship of the measurement endpoints and the assessment endpoints. The problem formulation for this site involves identifying the exposure pathways by which PCBs have or may migrate through the Manistique Harbor and River and ultimately to link these routes of migration to receptors and habitat in, on, and around the site.

2.1 ENVIRONMENTAL SETTING

The environmental setting is characterized to identify specific areas on or adjacent to the Manistique Harbor and River that contain ecological receptors and habitat. The characterization also identifies whether the site may be environmentally important, contain sensitive species (i.e., threatened or endangered) or contain habitat that sensitive species may utilize. The following description of the Manistique River and Harbor AOC was obtained from the 2002 Remedial Action Plan Update (Triad Engineering and TerraFirma Environmental, 2002).

2.1.1 Physical

The AOC lies primarily within the City of Manistique, beginning at the dam and extending through the Manistique Harbor to Lake Michigan. The east side of the river and harbor is primarily utilized for residential, business and recreational uses. The region of Schoolcraft County along the Lake

Michigan shoreline and including the AOC is fairly level and characterized by low sandy or gravely ridges alternating with swales and swamps. Soils surrounding the AOC are primarily sand underlain by limestone and dolomite.

The Manistique River substrate in the vicinity of the Manistique Papers, Inc. flume upstream of the U.S. 2 highway bridge is comprised primarily of limestone bedrock strewn with large boulders. The substrate below the US 2 highway bridge adjacent to the flume consists of rocks and smaller boulders overlying the limestone bedrock, with sand deposition occurring in the area of slower moving water on the east side of the River. Between the end of the rapids and the US 2 highway bridge the substrate is primarily sand and silt overlying limestone bedrock. The substrate downstream of the channels in the River and Harbor is a combination of sand and silt with some gravel, bedrock, cobble and slab wood. The deposition zones in the river and harbor continue to accumulate silt, primarily from erosion of bank materials in the upper watershed due to forestry practices.

Surveys conducted by MDNR in 1976, 1978 and 1985 documented that the substrate in the Manistique Harbor had been altered due to accumulation of sawdust and wood chips. These materials originated primarily from lumber-making and paper-making (from wood pulp) activities that historically occurred on the lower Manistique River. With the closing of the sawmills, improved wastewater treatment, and the switch from pulpwood to recycled magazines (materials including magazines plus mixed papers) as raw material at the paper mill, the discharge of the woody materials has been eliminated.

2.1.2 Biological

Aquatic habitat in the AOC downstream of the dam supports a variety of seasonal sport fish including northern pike, yellow perch, channel catfish, smallmouth bass, rock bass, walleye, chinook salmon, coho salmon, pink salmon, brown trout and steelhead. The area in the vicinity of the flume where the elevation of the river drops approximately 26 feet and flows over shelves of limestone and gravel bars is considered an excellent spawning location for many of the fish species. The remaining length of the river and harbor is basically at the level of Lake Michigan and is not considered important for spawning of fish.

Land habitat in the AOC is primarily sandy beach, low shrubs, and developed properties that can be used by shorebirds and gulls. In addition, bald eagles forage along the shoreline in the vicinity of the AOC. Waterfowl habitat is available primarily on the eastern shore of the river near U.S. 2, where the dead end channel creates a marsh. Waterfowl have also been observed along the river shoreline and around the islands created by the boat channels. There is little available wildlife habitat elsewhere in the AOC, since the entire site lies within the City of Manistique and the shoreline and nearby areas are relatively developed.

Table 2-1 presents the listed species and quality natural communities known to occur in Schoolcraft County. Table 2-2 presents the listed species and quality natural communities in the Schoolcraft County watersheds along Lake Michigan.

2.2 IDENTIFICATION OF EXPOSURE PATHWAYS

Exposure pathways describe the path a constituent takes from its source into the environment and ultimately to a receptor. The purpose of characterizing the exposure is to identify only complete exposure pathways for media and receptors from all possible routes of exposure that may exist at this site. Complete exposure pathways are more likely to contribute to potential risks resulting from that exposure. Exposure pathways considered to be complete exposures for the Manistique Harbor and River site are summarized as follows:

- **Benthic Invertebrates**—Benthic invertebrates can be significantly exposed through direct contact and dietary ingestion of PCBs in sediment, sediment pore water, and surface water.

- **Fish** —Fish can be exposed through dietary ingestion of PCB in sediment that accumulate in the food foraged by the fish, and any incidental ingestion or direct contact that occurs through the diet or through foraging. Exposure to PCBs dissolved in the water column can also occur through gills, dermis, and food ingestion.

- **Birds/Mammals**—Birds and mammals can be exposed through dietary ingestion of PCBs in sediment that accumulate in the food foraged by the bird or mammal, and any incidental ingestion or direct contact to PCBs in environmental media that occurs through the diet or through foraging or nesting activities. Birds and mammals that have the greatest degree of exposure are those that hunt and consume other organisms (especially fish) for food.

2.3 CONCEPTUAL EXPOSURE MODEL

A conceptual site model defines exactly how exposure to constituents might affect an ecosystem (Norton et al., 1992). The general taxonomic groups (i.e., mammals, birds, invertebrates, fish) potentially at risk from exposure at the Manistique River and Harbor and the associated fate and transport mechanisms have been summarized in a conceptual exposure pathway model (Table 2-3).

2.4 ASSESSMENT AND MEASUREMENT ENDPOINTS

The selection of assessment and measurement endpoints and their testable hypotheses is the final component in the problem formulation. Assessment and measurement endpoints primarily focus on the potential "link" between wildlife and food sources from within the Manistique Harbor and River and secondarily on direct contact exposures for organisms living in or on the Manistique Harbor and River. The food sources for species of avian and mammalian wildlife include fish, aquatic plants, invertebrates, algae and/or plankton from the water column. Exposure to wildlife through food-chain or trophic transfer as well as through direct contact exposure was considered in developing assessment and measurement endpoints.

2.4.1 Assessment Endpoints

Assessment endpoints are defined as explicit expressions of the environmental value that is to be protected (U.S. EPA, 1992). Each assessment endpoint represents a specific target receptor (or community) and function of interest to resource or risk managers. Multiple assessment endpoints are chosen to represent different trophic levels within a food web. Evaluation of target receptors from several trophic levels provides a more robust assessment of potential risks and addresses the range of sensitivities ultimately associated with site exposures. Because habitats and receptors at a site are unique, there is no standard list of assessment endpoints that can be used. The criteria (Suter, 1989; 1990; 1993) used to select assessment endpoints are as follows:

- Biological relevance to the ecosystem.
- Susceptibility to exposure and sensitivity to toxicity.
- Unambiguous operational definition (without this criteria, endpoints provide no direction for testing and modeling, and the results of an assessment tend to be ambiguous).
- Capability of being measured.
- Population abundance, community structure, or ecosystem productivity are examples of typically evaluated assessment endpoints.

Given the presence of PCBs in sediment and the potential for ecological exposure to occur from sediment, a set of assessment endpoints were developed for the purposes of achieving the specific goals of the ERA. The assessment endpoints represent potentially significant impacts to the Manistique River and Harbor eccosystem and are based on their ability to integrate modeled, field, or laboratory data with the individual assessment endpoint. Elevated levels of PCBs sediment and surface water are known to be toxic to fish and benthic organisms; thus toxicity to aquatic organisms and benthic invertebrates is an assessment endpoint for PCBs. The primary ecological threat of PCBs in ecosystems is not through direct exposure or acute toxicity. Instead, PCBs bioaccumulate in food chains and PCBs have been implicated as a cause of reduced reproductive success in piscivorous birds and mink (U.S. EPA, 1997). Therefore, reduced reproductive success in high trophic level species exposed through their diet is an important assessment endpoint for PCBs.

2.4.2 Measurement Endpoints

Measurement endpoints are the measurable environmental characteristics that are predictive of the selected assessment endpoint. Measurement endpoints approximate or predict conditions at a site (Maughan, 1993) and link the conditions to the assessment endpoint. Measurement endpoints can include both measures of effect (e.g., toxicity testing) and measures of exposure (e.g., concentrations in sediment). Because toxicity testing is outside the scope of this ERA, the measurement endpoints are not directly measured but are evaluated though calculations which evaluate exposure compared to the effects on the measurement endpoints. The criteria considered in the selection of measurement endpoints for the Manistique Harbor and River site include:

- Readily measured or evaluated.
- Corresponds to or is predictive of an assessment endpoint.
- Appropriate to the scale of the river and harbor, the exposure pathways, and the temporal dynamics.
- Low natural variability.
- Rapidly responding and sensitive to selected receptors.

Measurement endpoints (as measures of exposure) and the assessment objective being answered for this ERA are summarized by target receptor in Table 2-4.

2.5 IDENTIFICATION OF TARGET RECEPTORS

Target receptors were selected based on the concept that it is neither feasible nor cost-effective to measure constituent effects on all species inhabiting the aquatic and terrestrial habitat associated with the Manistique Harbor and River site. Consequently, target receptors have been selected and evaluated as surrogate species with a high level of sensitivity and exposure to constituents at the site. These target receptors are selected to provide the most conservative estimation of exposure for similar species within the same feeding guild. In addition, these target receptors (i.e., benthic organisms, feral fish, benthic organism, bald eagle, and mink) were evaluated in the pre-dredging qualitative ERA (Terra Inc., 1994). Also important to note is that even though target receptors were selected for evaluation in the ERA, these species are selected to represent exposures that other (similar) species with comparable feeding guilds may be receiving, and thus, serve as "surrogate" receptors.

2.5.1 Benthic Organisms

Historical activities, including sawmill operations and routine dredging, have severely altered the substrate available for the colonization of the river and harbor (Terra Inc., 1994). The substrate in the Manistique River and Harbor includes an accumulation of sawdust and wood chips from sawmills. Grain size analysis of the sediments indicate that the sediments are primarily fine sands, with some silty fine sands (Appendix A). While the substrate provided by the river and harbor does not provide habitat needed for a thriving benthic community, PCBs are known to adversely impact benthic organisms. Thus, the benthic organism population was selected as a receptor group in this evaluation.

2.5.2 Feral Fish Populations

The effects of persistent chlorinated hydrocarbons, such as PCBs, on the health of feral fish populations have been the focus of numerous scientific studies, especially in the Great Lakes (Terra, Inc., 1994). In studies with chlorinated hydrocarbons, the embryo/larval stage has been demonstrated to be the most sensitive period in an animal's life cycle (Terra Inc., 1994). Thus, the resident fish population was selected as a receptor group in this evaluation.

2.5.3 Bald Eagle

The bald eagle *(Haliaeetus leucocephalus)*, our national symbol, is federally designated threatened species (though the bald eagle is proposed for delisting). Bald eagles are generally restricted to coastal areas, lakes, and rivers. Bald eagle are known to occur within Schoolcraft County. Primarily carrion feeders, bald eagles eat dead or dying fish when available but will also catch live fish swimming near the surface or fish in shallow waters. Primary breeding sites include proximity to large bodies of open water and large nest trees with sturdy branches and areas of old growth timber with an open and discontinuous canopy. Bald eagles will migrate out of areas where lakes are completely frozen over winter but will remain as far north as the availability of open water and a reliable food supply allow (U.S. EPA 1993b). The bird's life span in the wild can reach 30 years. The birds travel over great distances, but normally return to nest within 100 miles of where they were originally raised.

While as a group birds tend to be more resistant to the acutely toxic effects of PCBs on mammals, the most sensitive endpoint in birds exposed to PCBs appears to be the egg and the effect on developing embryo (Terra Inc., 1994). The bald eagle is selected as a receptor species because of its status as a threatened species, its position at the top of the food chain, and its piscivorus feeding habits.

2.5.4 Mink

The mink (*Mustela vison*) is the most abundant and widespread carnivorous mammal in North America. Mink are found associated with aquatic habitats of all kinds, including rivers streams, lakes, ditches, swamps, marshes, and backwater areas. Mink prefer irregular shorelines to more open exposed banks and use brushy or wooded cover adjacent to the water where cover for prey is abundant and where downfall and debris provide den sites. Mink are active year round. The home range of a mink encompasses both their foraging areas around waterways and their dens. Mink are generally no more than 200 meters from water. During the mating season, males may range over

1000 hectares. Numerous studies have demonstrated that mink are among the most sensitive of the tested mammalian species to the toxic effects of PCBs (U.S. EPA, 1997). The mink is selected as a receptor species because of its PCB sensitivity, its position at the top of the food chain, and its piscivorus feeding habits.

Table 2-1
Listed Species and Natural Communities Occurring in Schoolcraft County
Manistique Harbor and River Site
Manistique, Michigan

Scientific Name	Common Name	Federal Status	State Status
Accipiter gentilis	Northern Goshawk		SC
Acipenser fulvescens	Lake Sturgeon		T
Asplenium trichomanes-ramosum	Green Spleenwort		T
Boloria frigga	Frigga Fritillary		SC
Buteo lineatus	Red-shouldered Hawk		T
Calypso bulbosa	Calypso or Fairy-slipper		T
Carex albolutescens	Greenish-white Sedge		T
Carex concinna	Beauty Sedge		SC
Carex nigra	Black Sedge		E
Carex novae-angliae	New England Sedge		T
Charadrius melodus	Piping Plover	LE	E
Cirsium pitcheri	Pitcher's Thistle	LT	T
Clematis occidentalis	Purple Clematis		SC
Collinsia parviflora	Small Blue-eyed Mary		T
Coturnicops noveboracensis	Yellow Rail		T
Danthonia compressa	Flat Oat Grass		SC
Danthonia intermedia	Wild Oat-grass		SC
Dendroica discolor	Prairie Warbler		E
Dendroica kirtlandii	Kirtland's Warbler	LE	E
Draba cana	Ashy Whitlow-grass		T
Dry northern forest	Dry Woodland, Upper Midwest Type		
Dry-mesic northern forest			
Eleocharis nitida	Slender Spike-rush		E
Emys blandingii	Blanding's Turtle		SC
Euconulus alderi	Land Snail		SC
Falco columbarius	Merlin		T
Gavia immer	Common Loon		T
Glyptemys insculpta	Wood Turtle		SC
Great blue heron rookery	Great Blue Heron Rookery		
Guppya sterkii	Land Snail		SC
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	T
Huperzia selago	Fir Clubmoss		SC
Interdunal wetland	Alkaline Shoredunes Pond/marsh, Great Lakes Type		
Intermittent wetland	Infertile Pond/marsh, Great Lakes Type		
Iris lacustris	Dwarf Lake Iris	LT	T
Ixobrychus exilis	Least Bittern		T
Juncus vaseyi	Vasey's Rush		T

Table 2-1 (Continued)
Listed Species and Natural Communities Occurring in Schoolcraft County
Manistique Harbor and River Site
Manistique, Michigan

Scientific Name	Common Name	Federal Status	State Status
Limestone pavement lakeshore			
Listera auriculata	Auricled Twayblade		SC
Littorella uniflora	American Shore-grass		SC
Lycaeides idas nabokovi	Northern Blue		T
Mesic northern forest			
Myriophyllum farwellii	Farwell's Water-milfoil		T
Open dunes	Beach/shoredunes, Great Lakes Type		
Oryzopsis canadensis	Canada Rice-grass		T
Pandion haliaetus	Osprey		T
Patterned fen	Rich Shrub/herb Fen, Upper Midwest Type		
Petasites sagittatus	Sweet Coltsfoot		T
Planogyra asteriscus	Eastern Flat-whorl		SC
Potamogeton confervoides	Alga Pondweed		SC
Pterospora andromedea	Pine-drops		T
Rallus elegans	King Rail		E
Rich conifer swamp			
Scirpus clintonii	Clinton's Bulrush		SC
Scirpus torreyi	Torrey's Bulrush		SC
Senecio indecorus	Rayless Mountain Ragwort		T
Solidago houghtonii	Houghton's Goldenrod	LT	T
Somatochlora incurvata	Incurvate Emerald		SC
Spring	Geographical Feature		
Stellaria longipes	Stitchwort		SC
Sterna hirundo	Common Tern		T
Tanacetum huronense	Lake Huron Tansy		T
Thalictrum venulosum var. confine	Veiny Meadow-rue		SC
Trimerotropis huroniana	Lake Huron Locust		T
Vaccinium cespitosum	Dwarf Bilberry		T
Vertigo elatior	Land Snail		SC
Vertigo hubrichti	Land Snail		SC
Vertigo paradoxa	Land Snail		SC
Williamsonia fletcheri	Ebony Boghaunter		SC
Wooded dune and swale complex			

State Status	Federal Status
E = endangered	LE = listed endangered
T = threatened	LT = listed threatened
SC = special concern	PDL = proposed delist

Source: MNFI, 2005. Current as of 1/4/2005.
http://web4.msue.msu.edu/mnfi/

Table 2-2
Listed Species and Natural Communities Occurring in Schoolcraft County Watersheds along Lake Michigan
Manistique Harbor and River Site
Manistique, Michigan

Watershed ID 4030112 58 5 (Tacoosh-Whitefish)			
Scientific Name	**Common Name**	**Federal Status**	**State Status**
Acipenser fulvescens	Lake Sturgeon		T
Glyptemys insculpta	Wood Turtle		SC
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	T
Pandion haliaetus	Osprey		T
Ranunculus lapponicus	Lapland Buttercup		T
Southern floodplain forest			
Wooded dune and swale complex			
Watershed ID 4060106 49 19 (Manistique)			
Scientific Name	**Common Name**	**Federal Status**	**State Status**
Coturnicops noveboracensis	Yellow Rail		T
Gavia immer	Common Loon		T
Juncus vaseyi	Vasey's Rush		T
Patterned fen	Rich Shrub/herb Fen, Upper Midwest Type		
Watershed ID 4060107 41L 28 (Brevoort-Millecoquins)			
Scientific Name	**Common Name**	**Federal Status**	**State Status**
Cirsium pitcheri	Pitcher's Thistle	LT	T
Great blue heron rookery	Great Blue Heron Rookery		
Interdunal wetland	Alkaline Shoredunes Pond/marsh, Great Lakes Type		
Iris lacustris	Dwarf Lake Iris	LT	T
Menegazzia terebrata	Lichen		
Tanacetum huronense	Lake Huron Tansy		T
Wooded dune and swale complex			

State Status
E = endangered
T = threatened
SC = special concern

Federal Status
LT = listed threatened
PDL = proposed delist

Note:

This is a listing of all known occurrences of threatened, endangered, and special concern species and high quality natural communities occurring within a watershed. The species and community information is derived from the MNFI database. The watersheds are based on the 14 digit Hydrologic Unit Codes (HUC).

The listing is based on the polygon representation of the occurrences. Consequently any single occurrence may span watershed boundaries and be listed in more than one watershed. This list is based on known and verified sightings of threatened, endangered, and special concern species and represents the most complete data set available. It should not be considered a comprehensive listing of every potential species found within a watershed. Because of the inherent difficulties in surveying for threatened, endangered, and special concern species and inconsistent of inventory effort across the State species may be present in a watershed and not appear on this list.

Source: MNFI, 2005. Current as of 1/4/2005.
http://web4.msue.msu.edu/mnfi/

Table 2-3
Ecological Conceptual Site Model
Manistique Harbor and River Site
Manistique, Michigan

Taxonomic Group	*Exposure Routes*				
	Sediment[1]	*Surface Water*[2]	*Direct Contact*[3]	*Incidental Ingestion*[4]	*Dietary Ingestion*[5]
Birds	X		X	X	X
Mammals	X		X	X	X
Aquatic invertebrates	X		X	X	X
Fish	X		X	X	X

Notes:

[1] Sediment exposure by birds and mammals is expected to occur only within shallow water areas (i.e., less than four foot water depth).
[2] PCBs were not detected in surface water samples; therefore this exposure route is not complete.
[3] Direct contact assumes contact with the receptor other than through ingestion.
[4] Incidental ingestion assumes indirect ingestion of contaminated media while grooming, eating, or foraging for food.
[5] Dietary ingestion assumes ingesting contaminants after uptake of constituents into sources of food (i.e., fish).

Table 2-4
Assessment and Measurement Endpoints
Manistique Harbor and River
Manistique, Michigan

Feeding Guild	Assessment Endpoint	Endpoint Objective	Surrogate Species or Community	Measures of Exposure	Measurement Endpoint
Benthic organisms	Benthic invertebrates are an important food source for many higher trophic level predators. They also provide an important role as decomposers/detritivores in nutrient cycling. *Assessment endpoint = preservation of the productivity (taxa richness and abundance) of benthic organisms.*	Are PCBs levels in sediment and surface water adversely affecting benthic and aquatic communities?	NA	Comparison of sediment and aqueous media concentrations with toxicity-based screening values.	Protection of benthic communities from reproductive or growth impairment from direct exposure to sediment and surface water.
Omnivorous fish	Omnivorous fish are an important prey item for higher trophic level predators. Through predation, they may also regulate population levels in lower trophic level fish and invertebrates. *Assessment endpoint = preservation of the productivity (taxa richness and abundance) of omnivorous fish.*	Are PCB levels in sediment and surface water adversely affecting fish populations? Are PCBs bioaccumulating in fish?	Catfish white sucker, longnose sucker,and shorthead redhorse	Tissue concentrations in fish. SPMD assays	Protection of omnivorous fish populations from reproductive or growth impairment from direct exposure to sediment and surface water.
Carnivorous fish	Carnivorous fish provide an important function for the aquatic environment by regulating lower trophic populations through predation. They are also an important prey item for many top level mammal and bird carnivores. *Assessment endpoint = preservation of the productivity (taxa richness and abundance) of carnivorous fish.*	Are PCBs in sediment and surface water adversely affecting carnivorous fish populations? Are PCBs bioaccumulating in fish?	Walleye, smallmouth bass	Tissue concentrations in fish. SPMD assays	Protection of carnivorous fish populations from reproductive or growth impairment from direct exposure to sediment and surface water.

Table 2-4
Assessment and Measurement Endpoints
Manistique Harbor and River
Manistique, Michigan
(Continued)

Feeding Guild	Assessment Endpoint	Endpoint Objective	Surrogate Species or Community	Measures of Exposure	Measurement Endpoint
Piscivorous mammal	Carnivorous mammals provide an important functional role to the environment by regulating lower trophic level prey populations. *Assessment endpoint = Survival, growth, and reproduction of piscivorus mammals.*	Are levels of PCBs in the diet of the mink excess of dietary levels indicative of reproductive or growth impairment in other species of piscivorous mammals? Are levels of PCBs in the sediments in excess of levels indicative of reproductive or growth impairment in other species of piscivorous mammals?	Mink	Food-chain modeling and comparison with TRVs.	Protection of the mink from reproductive or growth impairment within its foraging range from exposure through their diet.

Notes:
- Measurement endpoints are based on measures of exposure in the absence of site-specific field or toxicity testing.
- Endpoint objectives identify the primary questions of adverse impact that are being asked for each target receptor.

SECTION 3

SITE INVESTIGATION

A post-dredging site investigation was performed in September 2004 to collect the data and other resources needed to perform human health and ecological risk assessments for the post-dredging conditions in the Manistique Harbor and River site. The *Quality Assurance Project Plan (QAPP)* (WESTON 2004a) detailed the sampling activities that would be completed to support the risk assessments and a long-term monitoring program. A statistical sediment sampling strategy was developed in the QAPP. The approximately 1.7 mile long reach of the Manistique Harbor and River was divided into three distinct study areas, the River, Inner Harbor, and Outer Harbor, for the purposes of the investigation. Figure 3-1 illustrates the boundaries of these three areas. The investigation results are documented in the *Field Summary Report* (WESTON 2004b) and the *Data Evaluation Report* (WESTON 2005). The sampling activities focused on the collection of physical, chemical, and biological samples. The environmental media sampled included sediment, surface water, resident fish, caged fish, and semi-permeable membrane devices (SPMDs). All analytical data from this investigation is provided in the *Data Evaluation Report* (WESTON 2005). The focus of the analysis for each environmental sample type is:

- Sediment - to focus on changes in the areas with residual PCBs (≥1 part per million), known as the Area of Interest (AOI), with limited focus on areas with non-detected levels of PCBs, identified as the Background Zone (BZ).
- Surface Water - to determine if PCB concentrations in the water column are of concern and to evaluate the bioavailability of PCBs.
- Adult Resident Fish - to evaluate risk through the fish consumption pathway.
- Yearling Fish - to evaluate risk through the fish consumption pathway.
- Caged Fish - to assess if sediment-bound PCBs are potentially available to aquatic biota under the conditions in the field.

- Semi-Permeable Membrane Device (SPMD) - to assess if sediment-bound PCBs are potentially available to aquatic biota under the conditions in the field. SPMDs are especially useful for situations where caged fish will not survive.

The field events were conducted during two mobilization events. The objective of the first mobilization was to perform resident fish sampling, collect of collocated sediment and surface water samples, and deploy of the caged fish and SPMDs. The first mobilization was performed from 22 to 30 August 2004. The objectives of the second mobilization included collection of sediment samples from both BZ and AOI locations; sampling of surface water within the River, Inner Harbor, and Outer Harbor areas, and the retrieval of the caged fish and SPMDs. The second mobilization was performed from 7 September 2004 through 28 September 2004. The following subsections present a brief description of the sampling approach for each environmental medium. Detailed information on the site investigation and the analytical results in presented in the *Quality Assurance Project Plan (QAPP)* (WESTON 2004a), the *Field Summary Report* (WESTON 2004b) and the *Data Evaluation Report* (WESTON 2005).

3.1 SEDIMENT SAMPLING

The sampling design included the collection of 432 AOI samples, 100 BZ samples, and 10 sediment samples collocated with the caged fish samples. All sediment samples were collected using ponar sampling methodology, with a ponar dredge sampler used to collect a surficial sediment sample. The sampling design provided the geographic coordinates for each sediment sampling location; however, relocation of the sampling location was necessary in some instances to accommodate physical barriers (rocks, wood planks, ect). In all cases, U.S. EPA FIELDS personnel operated a global positioning system (GPS) unit and collected the geographic coordinate data at the actual sampling locations.

Of the 542 sediment locations contained in the sample design, 514 locations were successfully sampled. The remaining twenty eight locations could not be sampled due to: no sample recovery (rocks, wood planks, ect.) at 22 locations, sample locations outside of the study area at 4 locations (SD100, SD294, SD363, and SD429), a sample location collocated with another sample location (1 sample - SD009 and SD166), and a sample location way point accidentally deleted from file (1 location - SD484). Sediment sampling locations are provided in Figure 3-2. The sediment samples were submitted for analysis of PCBs through the U.S. EPA Contract Laboratory Program (CLP), total organic carbon (TOC) through the U.S. EPA Central Region Laboratory (CRL) and grain size (approximately 10% of locations) through Coleman Engineering of Iron Mountain, Michigan. The CLP laboratory for this investigation was Compuchem Environmental in Cary, North Carolina.

3.2 SURFACE WATER SAMPLING

Surface water sampling was completed during both the first and second mobilization. The sampling design included the collection of 30 grid locations selected from the River, Inner Harbor, and Outer Harbor (a total of 10 from each area) and twenty surface water samples collocated with the caged fish samples (10 samples at cage deployment, 10 samples at cage recovery). All surface water samples were collected using the peristaltic pump sampling methodology as described in the QAPP. At each sampling location, field measurements were collected for water depth and secchi disk transparency, and at each 2 foot depth interval for water temperature, pH, specific conductance, dissolved oxygen (DO), and current velocity. U.S. EPA FIELDS personnel collected the geographic coordinate data at each sampling location using a GPS unit.

Fifty surface water locations were proposed in the sample design; however, only 48 locations were successfully sampled. Two surface water samples (A2 and C2) were not collected at cage recovery because the caged fish samples were not recovered at these locations. Surface water sampling locations are provided in Figure 3-3. The surface water samples were submitted for analysis of PCBs through the CLP laboratory, and TOC, dissolved organic carbon, total dissolved solids (TDS), and total suspended solids (TSS) through the U.S. EPA CRL.

3.3 FISH SAMPLING

3.3.1 Resident Fish

The sample design detailed in the QAPP called for the collection of a total of forty eight adult fish (24 predator species and 24 bottom feeder species) and fifteen composite yearling samples (five samples from each of the three areas, as identified in Figure 3-1. The target adult species were catfish (*Ictalurus punctatus*) or carp (*Cyprinus carpio*) for the bottom feeder fish and walleye (*Stizostedion vitreum*) for the predator fish. However, alternative species for both predator and bottom feeder fish were acceptable in the event that an adequate number of target species fish could not be obtained. These alternate fish species were listed in the Michigan Department of Environmental Quality (MDEQ) GLEAS 31 Procedure (MDEQ 1995) and included northern pike (*Esox lucius*), small mouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), and rock bass (*Ambloplites rupestris*) as predator species and sucker species (*Catostomidae sp.*) as bottom feeder species.

Electroshocking methods were used to collect the majority of the resident fish as outlined in the QAPP. Additional methods utilized included trot line and fyke net fishing techniques. A total of 29 adult fish were caught and sampled (15 predator species and 14 bottom feeder species). Twenty-six of the fish were caught in the River and three were caught in the Inner Harbor. Fish collection did not yield any fish in the Outer Harbor. Fillet and carcass samples were then processed for each adult fish caught. Five yearling fish composite samples were also collected. Four of these samples were comprised of predator species and one sample was comprised of bottom feeder species. The yearling fish were grouped according to species and separated into groups large enough to provide 200 grams of sample. The fish tissue (adult fish fillet, adult fish carcass, and yearling composite) were submitted for analysis of PCBs, lipids, and moisture content through the CLP. The dorsal fin samples were submitted to the Lake Superior State University Aquatic Research Laboratory for age determination.

3.3.2 Caged Fish

The caged fish samples were deployed at the end of the first mobilization (26 - 27 August 2004) and were retrieved towards the end of the second mobilization (23 - 24 September 2004). The caged fish were deployed for a period of 28 days. Stone Creek, Inc. of Grant, Michigan supplied the channel catfish and the fish cages used for the study. Prior to deploying the caged fish, collocated surface water and sediment samples were collected at the planned location. The field parameters collected during this sampling were used to evaluate whether or not the location was suitable for the deployment of the caged fish. The caged fish were then deployed at the location and geographic position data were collected by U.S. EPA FIELDS. Caged fish locations A1 and A2 were adjusted because the originally planned locations were not deep enough to ensure that the cages would be fully submerged. The deployment locations of A1 and A2 were selected to ensure one location was present in the AOI (location A1) and one location was present in the BZ (location A2). Caged fish/SPMD sampling locations are presented in Figure 3-4. Each cage was weighted and deployed from a boat piloted by U.S. EPA FIELDS. Cages B1, B2, D1, and A2 were redeployed after the cages were disturbed by either fishing activities or strong storm surge; cage A1 was lost at this time. The cage at A2 was redeployed at location A1 since location A1 is within the AOI. U.S. EPA divers assisted with the retrieval of the fish cages from 23 - 24 September 2004. All but two fish cages were recovered (the cage originally deployed A1 and the cage deployed at C2). Fish were recovered from the following cages: B1 (15 fish recovered; 4 replicate samples), B2 (7 fish recovered; 2 replicate samples), D1 (24 fish recovered; 6 replicate samples), and E2 (27 fish recovered; 7 replicate samples). Cages C1 and E1 were damaged and did not contain fish. All recovered fish were measured, weighed, and inspected for any deformities. The fish recovered from a cage location were separated into groups large enough to provide 200 grams of sample (as many replicate samples as possible were prepared from each cage) and the fish were submitted for analysis of PCBs and lipids through the U.S. EPA CLP.

3.3.3 Semi-Permeable Membrane Device

The SPMDs were deployed at the same time and at the same locations as the caged fish. In general, six SMPDs were deployed in each cage, with the exception of four SPMDs deployed at B1 location and five SPMDs deployed at A2 location. At each location, three SPMDs were deployed along the horizontal plane (relative to the river/harbor floor) and three were deployed vertically in the water column. At locations C1, E1, and E2, the vertical SPMDs were mounted on a PVC pipe (5 to 10 feet in length) extending up from the cage. At the other locations, the vertical SPMDs were mounted on the fish cage, approximately two feet from the bottom of the cage. The SPMDs were deployed following the procedures listed in the QAPP. Two field atmospheric field blank samples were located approximately 15 feet above the ground at opposite ends of the harbor for the duration of the SPMD deployment.

As previously discussed, cages B1, B2, D1, and A2 were redeployed after the cages were disturbed by either fishing activities or strong storm surge. At locations D1 and A2, only the SPMDs were redeployed because the fish did not survive. The cage recovered along the beach (A2 location) was redeployed at the A1 location to ensure that at least one pair of SPMDs were located in the AOI in the western portion of the Outer Harbor.

From 23 - 24 September 2004, the SPMDs were recovered from all locations except A2 and C2. In addition, the vertical SPMD was not recovered at location B2. While the cage that was originally deployed at the A1 location was not recovered (only the redeployed fish cage from the A2 location was found in this area), one canister was found in the vicinity of the A1 location. The three SPMDs in this canister were submitted for analysis as samples MH1-SPA1-07 through 09. The U.S. EPA divers observed the cages at locations C1, E1, and E2 (cages with PVC extensions for the vertical SPMDs) were on their side.

Following their retrieval, the SPMDs were sent to STS Laboratories for cleanup and dialysis (extraction). The extract was forwarded to a CLP laboratory for analysis of PCBs.

FIGURES

Harbor and River Outlines

- Inner Harbor
- Outer Harbor
- River

N

0 400 Feet

Notes: Coordinates: UTM, Nad83, Zone16, Meters

Work Assignment No. 236-TATA-05FV
Document Control No. RFW236-2F-ASQP

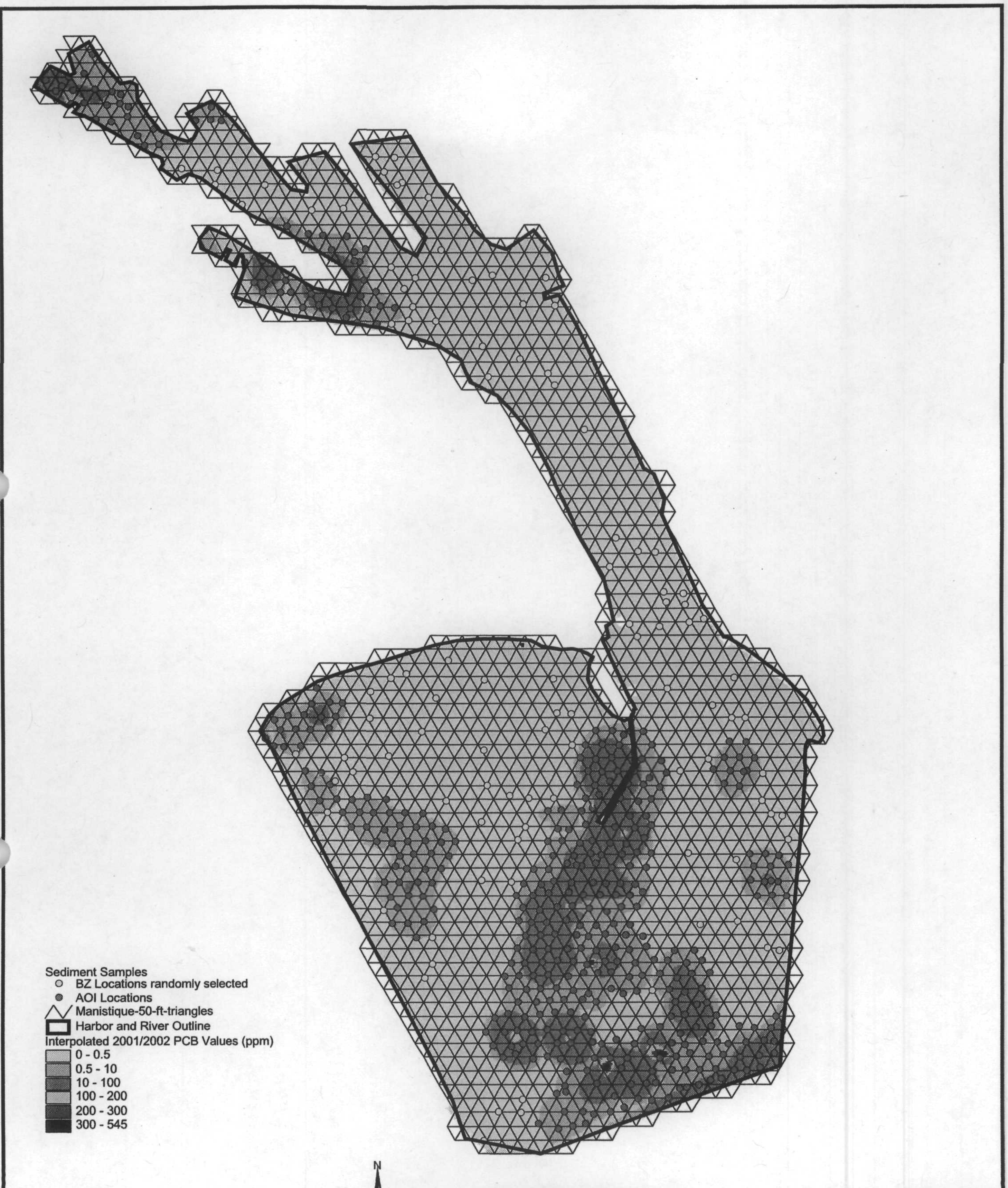
Figure 3-1

WESTON

Weston Solutions, Inc.
750 E. Bunker Ct.
Suite 500
Vernon Hills, IL 60061

River, Inner Harbor, and Outer Harbor Location Map

Manistique Harbor, Michigan



Work Assignment No. 236-TATA-05FV
Document Control No. RFW236-2F-ASQP

Figure 3-2

Notes:
50ft Triangular Sediment Grid

Coordinates: UTM, Nad83, Zone16, Meters

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Vernon Hills, IL 60061

Sediment Sampling Location Map

Manistique Harbor, Michigan

● Surface Water Samples
Harbor and River Outlines
Inner Harbor
Outer Harbor
River

N

0 400 Feet

Notes:
Coordinates: UTM, Nad83, Zone16, Meters

Work Assignment No. 236-TATA-05FV
Document Control No. RFW236-2F-ASQP

Figure 3-3

WESTON

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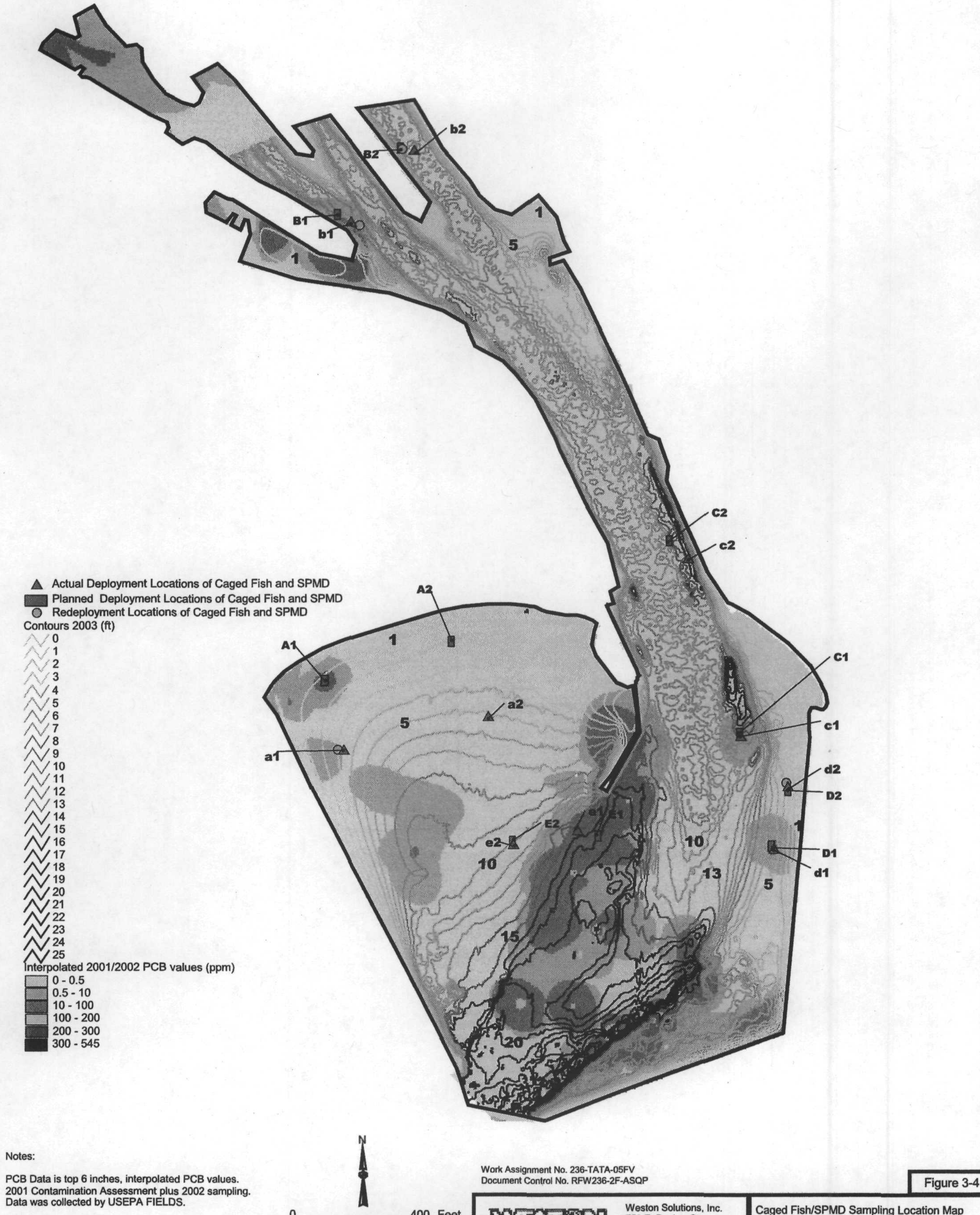
Suite 500
Vernon Hills, IL 60061

Surface Water Sampling Location Map

Manistique Harbor, Michigan



Notes:

PCB Data is top 6 inches, interpolated PCB values.
2001 Contamination Assessment plus 2002 sampling.
Data was collected by USEPA FIELDS.

Coordinates: UTM, Nad83, Zone16, Meters

Work Assignment No. 236-TATA-05FV
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Figure 3-4

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Caged Fish/SPMD Sampling Location Map

Manistique Harbor, Michigan

SECTION 4

CHARACTERIZATION OF EXPOSURE

The characterization of exposure identifies the magnitude and frequency by which target receptors are exposed to contaminants that have migrated or may potentially migrate through various exposure pathways. This involves site-specific quantification of the levels of contaminants present in the environment as well as site-specific quantification of the levels of contaminants that may be entering each individual target receptor. The specific objectives of this characterization step are to identify the following:

- Magnitude and frequency of environmental exposures.
- Magnitude and frequency of receptor intake.

4.1 ESTIMATION OF ENVIRONMENTAL EXPOSURE

Estimation of environmental exposure involves the quantification of contaminants at the point of likely receptor exposure. Contaminant concentrations at these points (called exposure point concentrations or EPCs) are critical in determining constituent intake and subsequent risk to target receptors. EPCs are developed by the habitat and target receptors identified in the problem formulation. The exposure point concentration is intended to represent a reasonable maximum estimate of the concentration a receptor is likely to be exposed to over time. This approach to characterizing exposure facilitates the prioritization of risk management decisions for areas where ecological receptors are more likely to occur. The fish tissue and sediment data, including EPCs, are summarized in Table 4-1. All data used in the ERA (i.e., sediment and fish tissue) is presented in Appendix A.

4.1.1 Sediment

Two exposure point concentrations were evaluated for benthic organism exposure to sediment - the arithmetic average concentration and the 95 percent upper confidence limit (95% UCL) on the arithmetic mean. The 95% UCL was calculated according to the distribution assumption of the dataset (i.e., normal, lognormal, distribution-free) using EPA's ProUCL (Version 3.0) software (U.S. EPA, 2003b). For exposure of benthic organisms, all sediment locations in the harbor and river were used in the EPC calculations. In addition, sediment data was summarized by location (i.e., inner harbor, outer harbor, and river).

Two exposure point concentrations were evaluated for higher level organism exposure to sediment - the maximum detected concentration and the 95% UCL on the arithmetic mean. The highest concentration of duplicate samples was used in the 95% UCL calculations. The 95 % UCL was calculated according to the distribution of the dataset (i.e., normal, lognormal, distribution-free) using EPA's ProUCL (Version 3.0) software (U.S. EPA, 2003b). The depth of the water in the harbor and river will restrict wildlife access to sediment. Higher level organism exposure to sediments considers only those samples collected from locations with a water depth of less than or equal to four feet. Thus, all sample locations with deeper water depths were not included in the EPC calculations. Maximum and average sediment concentrations are evaluated to account for possible sediment disturbance.

4.1.2 Surface Water

PCBs were not detected in surface water at concentrations above method detection limits. This environmental medium is not evaluated further.

4.1.3 Tissue

The target receptors associated with the Manistique Harbor and River site are exposed through the ingestion of constituents in their food, called dietary exposure. Dietary exposure can occur with constituents that have migrated from the contaminants in environmental media into plant and animal tissues. This process of migration and exposure through the diet is called "food-chain bioaccumulation." Constituents are often measured directly in tissues as a way to estimate the exposure a target receptor might receive in their diet. Field measured tissue data was collected including adult and yearling resident fish. Fish tissue was collected from bottomfeeder (trophic level 3) and predator (trophic level 4) species. The target adult species were catfish or carp (*Cyprinus carpio*) for the bottomfeeder fish and walleye for the predator fish. However, alternative species for both bottomfeeder and predator species were collected because an adequate number of target species fish could not be obtained. A total of 29 adult fish were caught and sampled (15 predators and 14 bottomfeeders). Bottomfeeder species collected included catfish (*Ictalurus punctatus*), white sucker (*Catostomus commersonii)*, longnose sucker (*Catostomus catostomus*), and shorthead redhorse (*Moxostoma macrolepidotum*). Predator species collected included walleye (*Stizostedion vitreum*) and smallmouth bass (*Micropterus dolomieui*). Yearling composite samples included walleye, rock bass (*Ambloplites rupestris*), shorthead redhorse, and small mouth bass.

Two exposure point concentrations were evaluated for fish - the maximum detected concentration and the 95% UCL on the arithmetic mean. The highest concentration of duplicate samples was used in the 95% UCL calculations. The 95% UCL was calculated according to the distribution of the dataset (i.e., normal, lognormal, distribution-free) using EPA's ProUCL (Version 3.0) software (U.S. EPA, 2003b). Bioaccumulation of PCBs differs by fish species, so both maximum and average concentrations are evaluated to account for species differences. Whole fish concentrations were calculated based on the relative wet weights of the tissues. The PCB concentrations in the fillet and in the carcass were multiplied by their individual wet weights, the two products were added and then divided by the total fish wet weight. Non-detects were included at one-half the detection limit.

Composite whole fish samples were collected for yearling fish. Since wildlife consumes differing amounts of fish based on the trophic level of the fish, fish tissue was segregated into bottomfeeders (trophic level 3) and predators (trophic level 4).

4.2 ESTIMATION OF RECEPTOR UPTAKE

For target receptors or communities that are exposed directly to the media in which they live (such as benthic invertebrate and fish), uptake is expressed in terms of measured concentrations of constituents in the media in which they reside (for example the concentration of constituents in sediment are used to directly estimate the intake received by benthic organisms). For target receptors that are exposed through the ingestion, inhalation, or dermal contact exposure routes, daily exposure intake models were developed which express exposure in terms of constituent intake per kilogram of body weight per day (mg/kg-day). While dermal contact and inhalation can contribute significant constituent uptake to a receptor's total intake, limited information exists for quantifying these exposure routes when compared to the current availability of information for quantifying ingestion. Thus, only ingestion models were used to estimate uptake by avian and mammalian receptors.

The algorithm used to calculate exposure of avian and mammalian target receptors through ingestion of sediment and tissue follows the generic equation presented above and is described as follows:

$$EDI_{medium} = \frac{\left(C_{medium} \times IR_{medium}\right) \times DCF \times SUF}{BW}$$

where:

EDI_{medium} = Estimated daily intake of constituent through sediment or tissue ingestion (mg/kg/day), normalized for body weight.

C_{medium} = Concentration of constituent in sediment or tissue (dry or wet weight basis) (mg/kg).

IR_{medium}	=	Ingestion rate of sediment or tissue by receptor (dry or wet weight basis, on a consistent basis with the constituent concentration) (kilograms/day). For ingestion rates reported on a wet weight basis, calculation of ingestion rate on a dry weight basis is as follows:

$$IR_{dry} = IR_{wet} \times (1 - \%\ moisture)\ (U.S.\ EPA\ 1993b).$$

DCF	=	Dietary Composition Factor (assumed percent dietary intake from the site).
SUF	=	Site Use Factor (assumed percent use of the site).
BW	=	Body Weight (kilograms).

Wet weight tissue concentrations can be converted to dry weight using the following equation (U.S. EPA, 1993b):

$$C_{tissue}(DW) = \frac{C_{tissue}(WW)}{\%\,Solids}$$

where:

$C_{tissue}(DW)$	= Concentration in tissue (dry weight).
$C_{tissue}(WW)$	= Concentration in tissue (wet weight)
% Solids	= 1-% Moisture

Total ingestion exposure for a target receptor from multiple sources is considered cumulative. The generic equation for ingesting multiple sources of constituents from food, sediment, and water can be described as follows:

$$EDI_{total} = EDI_{sediment} + EDI_{water} + EDI_{food}$$

where:

EDI_{total}	=	Total estimated daily intake (mg/kg/day).
$EDI_{sediment}$	=	Estimated daily intake of constituent sediment ingestion (mg/kg/day).

EDI_{water}	=	Estimated daily intake of constituent water ingestion (mg/kg/day).
EDI_{food}	=	Estimated daily intake of constituent from ingestion of food, either forage or prey (mg/kg/day).

While dermal contact and inhalation can contribute significant constituent uptake to a receptor's total intake, these routes are not quantified because limited information exists for quantifying these exposure routes when compared to the current availability of information for quantifying ingestion. Assumptions for each of the exposure parameters that comprise total intake were based on literature as well as site-specific information.

Exposure parameters that were considered in quantifying exposure to all target receptors are listed below.

- Intake rates and body weights.
- Dietary composition factor (percent).
- Tissue moisture (percent).
- Site use factor (percent).

In this ERA, wholebody fish tissue has been assumed to compose 100 percent of a receptor's diet. Specific intake equations and parameters for the target receptors selected in this risk assessment are presented in detail in the sections below.

4.2.1 Bald Eagle

The bald eagle inhabits the Manistique Harbor and River AOC and was selected as a target receptor for assessment of potential food-chain bioaccumulation from sediments into sensitive species of piscivorus birds. The ingestion of fish and incidental ingestion of sediment represent the primary routes of exposure to the eagle. While consumption of water is another potential exposure route, PCBs were not detected in this medium; thus, surface water intake was not evaluated for this target receptor. The specific exposure parameters and references that were used in quantifying exposure of the bald eagle are presented in Table 4-2.

4.2.2 Mink

The mink inhabits the Manistique Harbor and River AOC and was selected as a target receptor for assessment of potential food-chain bioaccumulation from sediments into species of piscivorus mammals. The ingestion of fish and incidental ingestion of sediment represent the primary routes of exposure to the mink. While consumption of water is another potential exposure route, PCBs were not detected in this medium; thus, surface water intake was not evaluated for this target receptor. The specific exposure parameters and references that were used in quantifying exposure of the mink are presented in Table 4-3.

TABLE 4-1
DATA SUMMARY
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, SCHOOLCRAFT COUNTY, MICHIGAN

Analyte	Detected Samples	Units	Detected Concentration		Quantitation Limit		Mean	Standard Deviation	Distribution	95 UCL*	Basis
			Minimum	Maximum	Minimum	Maximum					
SEDIMENT (Only locations with < 4 ft of water)											
Aroclor 1016	0/57	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1221	0/57	ug/kg	–	–	80	370	–	–	–	–	–
Aroclor 1232	0/57	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1242	0/57	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1248	0/57	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1254	12/57	ug/kg	15	4100	38	130	197	671	Non-parametric	752	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1260	3/57	ug/kg	19	1200	38	130	40	157	Non-parametric	140	95% Chebyshev (Mean, Sd) UCL
Total PCBs	15/57	ug/kg	15	4100	78	270	237	678	Non-parametric	798	97.5% Chebyshev (Mean, Sd) UCL
SEDIMENT (all locations)											
Aroclor 1016	0/514	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1221	0/514	ug/kg	–	–	80	370	–	–	–	–	–
Aroclor 1232	0/514	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1242	0/514	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1248	164/514	ug/kg	15	54000	38	180	550	3202	Non-parametric	1432	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1254	88/514	ug/kg	7.5	17000	38	130	190	995	Non-parametric	484	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1260	27/514	ug/kg	7.5	8500	38	130	133	600	Non-parametric	298	97.5% Chebyshev (Mean, Sd) UCL
Total PCBs	180/514	ug/kg	15	54000	78	270	740	3488	Non-parametric	1686	97.5% Chebyshev (Mean, Sd) UCL
SEDIMENT (Outer Harbor)**											
Aroclor 1016	0/403	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1221	0/403	ug/kg	–	–	80	370	–	–	–	–	–
Aroclor 1232	0/403	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1242	0/403	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1248	130/403	ug/kg	15	54000	38	180	530	3525	Non-parametric	1626	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1254	75/403	ug/kg	15	17000	38	130	192	1078	Non-parametric	528	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1260	18/403	ug/kg	7.5	8500	38	130	124	603	Non-parametric	255	95% Chebyshev (Mean, Sd) UCL
Total PCBs	152/403	ug/kg	15	54000	78	270	723	3753	Non-parametric	1891	97.5% Chebyshev (Mean, Sd) UCL
SEDIMENT (River)**											
Aroclor 1016	0/80	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1221	0/80	ug/kg	–	–	80	370	–	–	–	–	–
Aroclor 1232	0/80	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1242	0/80	ug/kg	–	–	38	180	–	–	–	–	–
Aroclor 1248	38/80	ug/kg	19	10000	38	180	771	1705	Non-parametric	2589	99% Chebyshev (Mean, Sd) UCL
Aroclor 1254	14/80	ug/kg	19	4800	38	130	220	674	Non-parametric	685	97.5% Chebyshev (Mean, Sd) UCL
Aroclor 1260	9/80	ug/kg	11.5	4800	38	130	200	657	Non-parametric	635	97.5% Chebyshev (Mean, Sd) UCL
Total PCBs	38/80	ug/kg	23	15180	78	270	891	2385	Non-parametric	2558	97.5% Chebyshev (Mean, Sd) UCL
SURFACE WATER											
Aroclor 1016	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Aroclor 1221	0/40	ug/L	–	–	0.4	0.44	–	–	–	–	–
Aroclor 1232	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Aroclor 1242	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Aroclor 1248	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Aroclor 1254	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Aroclor 1260	0/40	ug/L	–	–	0.2	0.22	–	–	–	–	–
Total PCBs	0/40	ug/L	–	–	0.4	0.44	–	–	–	–	–
ADULT FISH TISSUE											
Adult Resident TL-3											
Aroclor 1016	0/14	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1221	0/14	mg/kg	–	–	0.2	0.2	–	–	–	–	–
Aroclor 1232	0/14	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1242	0/14	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1248	10/14	mg/kg	0.09	0.71	0.099	0.099	0.217	0.199	Gamma	0.340	Approximate Gamma UCL
Aroclor 1254	11/14	mg/kg	0.04	0.51	0.099	0.099	0.178	0.130	Gamma	0.258	Approximate Gamma UCL
Aroclor 1260	12/14	mg/kg	0.04	0.13	0.099	0.099	0.065	0.031	Normal	0.079	Student's t UCL
Total PCBs	14/14	mg/kg	0.04	1.16	0.099	0.099	0.39	0.34	Gamma	0.621	Approximate Gamma UCL
Adult Resident TL-4											
Aroclor 1016	0/15	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1221	0/15	mg/kg	–	–	0.2	0.2	–	–	–	–	–
Aroclor 1232	0/15	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1242	0/15	mg/kg	–	–	0.099	0.099	–	–	–	–	–
Aroclor 1248	4/15	mg/kg	0.06	0.163	0.099	0.099	0.061	0.024	Non-parametric	0.071	Student's t UCL
Aroclor 1254	12/15	mg/kg	0.07	0.44	0.099	0.099	0.130	0.111	Lognormal	0.195	H-UCL
Aroclor 1260	11/15	mg/kg	0.04	0.19	0.099	0.099	0.089	0.055	Non-parametric	0.151	95% Chebyshev (Mean, Sd) UCL
Total PCBs	15/15	mg/kg	0.07	0.61	0.099	0.099	0.19	0.16	Gamma	0.27	Approximate Gamma UCL

TABLE 4-1 (Continued)
DATA SUMMARY
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, SCHOOLCRAFT COUNTY, MICHIGAN

Analyte	Detected Samples	Units	Detected Concentration		Quantitation Limit		Mean	Standard Deviation	Distribution	95 UCL*	Basis
			Minimum	Maximum	Minimum	Maximum					
YEARLING FISH TISSUE											
Yearling Resident TL-3											
Aroclor 1016	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1221	0/1	ug/kg	--	--	200	200	--	--	--	--	--
Aroclor 1232	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1242	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1248	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1254	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1260	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Total PCBs	0/1	ug/kg	--	--	99	99	--	--	--	--	--
Yearling Resident TL-4											
Aroclor 1016	0/4	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1221	0/4	ug/kg	--	--	200	200	--	--	--	--	--
Aroclor 1232	0/4	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1242	0/4	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1248	0/4	ug/kg	--	--	99	99	--	--	--	--	--
Aroclor 1254	2/4	ug/kg	140	160	99	99	150	--	--	--	--
Aroclor 1260	1/4	ug/kg	--	39	99	99	--	--	--	--	--
Total PCBs	2/4	ug/kg	140	199	99	99	169.5	--	--	--	--

* Calculated using ProUCL version 3.0 (U.S. EPA, 2003b)
NA - Not available.
All fish tissue presented on a wet weight basis.
All sediment presented on a dry weight basis.
Only sample locations with water depth less
** PCBs were not detected in samples collected from the inner harbor

TL-3 = Trophic Level 3.
TL-4 = Trophic Level 4.
95 UCL = 95 percent upper confidence limit.
ug/kg = microgram per kilogram.
ug/L = microgram per liter.

Table 4-2
Parameters Used in Bald Eagle Intake Calculations
Manistique Harbor and River Site
Manistique, Michigan

Parameter	Average Adult	Units	Reference/Notes
Intake Rate$_{tissue}$	Total - 0.47883; TL3 - 0.371; TL4 - 0.0929; PB- 0.00283 Other - 0.0121	kg/day (wet weight)	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Intake Rate$_{sediment}$	0.001125	kg/day (dry weight)	Ingestion of sediment is negligible; conservatively estimated at 1% of dry weight total ingestion rate, where: $IR_{sediment\text{-}dry} = IR_{tissue\ dry} \times 0.01$ $IR_{tissue\ dry} = IR_{tissue\ wet} \times (1 - \%\ moisture)$
Intake Rate$_{water}$	0.160	L/day	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Tissue moisture	76.5 (62.5 - 80.8)	Percent	Average of all fish tissue; See Table A-2.
Dietary composition factor	100	Percent	Based on a conservative assumption of 100% dietary intake from the site; assumes 100% intake of most contaminated fraction (i.e., highest contaminant concentration regardless of food type).
Site use factor	100	Percent	Based on a conservative foraging territory range encompassing the site.
Adult body weight	4.6	kg	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.

Notes:
kg = Kilograms
IR = Intake Rate
WT = Weight
TL3 = Trophic level 3 fish
TL4 = Trophic level 4 fish
PB = Piscivorous birds
Other = non-aquatic birds and mammals

Table 4-3
Parameters Used in Mink Intake Calculations
Manistique Harbor and River Site
Manistique, Michigan

Parameter	Average Adult	Units	Reference/Notes
Intake $Rate_{tissue}$	Total - 0.1767; TL3 - 0.159 Other - 0.0177	kg/day (wet weight)	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Intake $Rate_{sediment}$	0.000415	kg/day (dry weight)	Ingestion of sediment is negligible; conservatively estimated at 1% of dry weight total ingestion rate, where: $IR_{sediment\text{-}dry} = IR_{tissue\ dry} \times 0.01$ $IR_{tissue\ dry} = IR_{tissue\ wet} \times (1 - \%\ moisture)$
Intake $Rate_{water}$	0.081	L/day	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Tissue moisture	76.5 (62.5 - 80.8)	Percent	Average of all fish tissue; See Table A-2.
Trophic level of prey	TL3 - 90; Other - 10	Percent of diet	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Dietary composition factor	100	Percent	Based on a conservative assumption of 100% dietary intake from the site; assumes 100% intake of most contaminated fraction (i.e., highest contaminant concentration regardless of food type).
Site use factor	100	Percent	Based on a conservative foraging territory range encompassing the site.
Adult body weight	0.80	kg	From Table D-2, Exposure Parameters for the Five Representative Species Identified for Protection, EPA, 1995. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.

Notes:

kg	=	Kilograms
IR	=	Intake Rate
WT	=	Weight
TL3	=	Trophic level 3 fish
TL4	=	Trophic level 4 fish
PB	=	Piscivorous birds
Other	=	non-aquatic birds and mammals

SECTION 5

CHARACTERIZATION OF EFFECTS

The ecological effects characterization presents information on the toxicity of the PCBs to ecological species in more detail. A toxicological profile of PCBs is provided in Appendix C. This toxicity information has been specifically used to develop toxicity reference values (TRVs) for the selected target receptors and communities. Scientific literature were reviewed for media-specific and species-specific toxicity data. TRVs based on media concentrations are used for fish and benthic organisms and TRVs based on dose are used for bird and mammal receptors. TRVs were obtained from the sources listed below.

- Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS) on-line database (http://risk.lsd.ornl.gov/rap_hp.shtml).
- U.S. EPA Region 9 Biological Technical Assessment Group (BTAG) (http://www.dtsc.ca.gov/ScienceTechnology/eco.html#BTAG)
- Final Baseline Human Health and Ecological Risk Assessment. Lower Fox River and Green Bay, Wisconsin. Remedial Investigation and Feasibility Study (The Retec Group, 2002).
- U.S. Army Corps of Engineers/U.S. Environmental Protection Agency Environmental Residue-Effects Database (ERED). (http://www.wes.army.mil/el/ered)

5.1 DERIVATION OF TRVs FOR BENTHIC ORGANISMS AND FISH

TRVs based on media concentrations are not specific to individual species but instead are applicable to groups of organisms or communities occupying the same medium (e.g., invertebrates in sediment, aquatic biota in surface water). For example, ambient water quality criteria for chemicals in surface water are designed to be protective of all aquatic biota occupying the same aquatic community or body of water. TRVs based on media concentrations are expressed as a concentration (e.g., mg-chemical/kg-sediment).

5.1.1 Sediment TRVs

Various agencies have developed sediment quality criteria and benchmarks for the assessment of toxicological effects on sediment-associated biota (ORNL 2004). Note that these benchmarks are not remediation goals; remediation goals must consider the adverse effects on habitat and remobilization of contaminants caused by removal or remediation of sediments (Jones et al., 1996). The sediment benchmarks should not be considered as the sole measure of sediment toxicity; rather, field studies and toxicity tests are primary indicators of sediment toxicity (Jones et al., 1996). The sediment benchmarks provide a means for determining which chemicals are most likely causing toxicity as presented in Jones et al. (1996). The use of multiple benchmarks also provides an indication of the likelihood and nature of effects. For example, exceedance of only one conservatively estimated benchmark may provide weak evidence of real effects, whereas exceedance of multiple benchmarks of varying conservatism may provide strong evidence of real effects (Jones et al., 1996). Sediment benchmarks are presented in Table 5-1.

The sediment benchmarks were obtained from the ORNL RAIS (2004) database, and are a compilation of the following sources (ORNL, 2004):

Assessment and Remediation of Contaminated Sediments (ARCS) Program

Source: U.S. Environmental Protection Agency. 1996a. *Calculation and evaluation of sediment effect concentrations for the amphipod Hyalella azteca and the midge Chironomus riparius.* EPA 905/R96/008. Great Lakes National Program Office, Chicago, IL. http://www.cerc.usgs.gov/clearinghouse/data/brdcerc0004.html) (http://www.cerc.usgs.gov/pubs/sedtox/sec-dev.html)

The majority of the data are for freshwater sediments. The representative effect concentration selected from among the high no-effect-concentrations (NEC) for *Hyalella azteca* and *Chironomus riparius* are presented in U.S. EPA (1996a). It is a concentration above which statistically significant adverse biological effects always occur. Effects may occur below these levels (U.S. EPA, 1996a).

The representative effect concentration selected from among the ER-Ls and TELs for *Hyalella azteca* and *Chironomus riparius* are presented in U.S. EPA (1996a). The TEC is the geometric mean of the 15th percentile in the effects data set and the 50th percentile in the no effects data set. It is a concentration that represents the upper limit of the range dominated by no effects data. Concentrations above the TEC may result in adverse effects to these organisms; concentrations below the TEC are unlikely to result in adverse effects.These are possible-effects benchmarks (U.S. EPA, 1996a).

The representative effect concentration selected from among the ER-Ms and PELs for *Hyalella azteca* and *Chironomus riparius* are presented in U.S. EPA (1996a). The PEC is the geometric mean of the 50th percentile in the effects data set and the 85th percentile in the no effects data set. It represents the lower limit of the range of concentrations usually associated with adverse effects. A concentration greater than the PEC is likely to result in adverse effects to these organisms. These are probable-effects benchmarks.

Canadian ISQG and PEL

Source: Environment Canada's *Canadian Environmental Quality Guidelines* web page at http://www.ec.gc.ca/ceqg-rcqe/English/Ceqg/Sediment/default.cfm and http://www.ccme.ca/assets/pdf/e1_06.pdf. Updated 2002.

The Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment (CCME) developed chemical concentrations recommended to support and maintain aquatic life associated with bed sediments. These values are derived from available scientific information on biological effects of sediment-associated chemicals and are intended to support the functioning of healthy ecosystems. The Sediment quality guidelines protocol relies on the National Status and Trends Program approach and the Spiked-Sediment Toxicity Test approach. The Interim Sediment Quality Guidelines (ISQG) correspond to threshold level effects below which adverse biological effects are not expected. The Probable Effects Levels (PEL) correspond to concentrations above which adverse biological effects are frequently found.

Consensus PEC and TEC

Source: MacDonald, D.D. , C.G. Ingersoll, and T.A. Berger. 2000. "Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems". *Arch. Environ. Contam. Toxicol. 39: 20-31.*

Consensus-based Sediment Quality Guidelines (SQG) represent the geometric mean of published SQGs from a variety of sources. Sources for Probable Effect Concentrations (PEC) include probable effect levels, effect range median values, severe effect levels, and toxic effect thresholds (see MacDonald et al. 2000 for references). PECs are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are expected to occur more often than not. TECs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are not expected.

EPA Region 4

Source: U.S. Environmental Protection Agency Region IV. 1995b. *Ecological screening values, Ecological Risk Assessment Bulletin No. 2,* Waste Management Division. Atlanta, Georgia. (superceded by http://www.epa.gov/region04/waste/ots/ecolbul.htm#tbl3).

The higher of the EPA Contract Laboratory Program Practical Quantitation Limit and the Effects Value, which is the lower of the ER-L and the TEL. These are possible effects benchmarks.

EPA Region 5 ESLs - Sediment

Source: U.S. Environmental Protection Agency Region V. 2003a. *August 2003 revision of the ESLs (formerly EDQLs)* at http://www.epa.gov/reg5rcra/ca/ESL.pdf

The ESL reference database consists of Region 5 media-specific (soil, water, sediment, and air) Ecological Screening Levels (ESLs) for RCRA Appendix IX hazardous constituents. The ESLs are initial screening levels with which the site contaminant concentrations can be compared. The ESLs help to focus the investigation on those areas and chemicals that are most likely to pose an unacceptable risk to the environment. ESLs also impact the data requirements for the planning and implementation of field investigations. ESLs alone are not intended to serve as cleanup levels.

EPA Region 6 Ecological Screening Benchmarks: Freshwater Sediment

Source: Texas Natural Resource Conservation Commission. 2001. *Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas.* Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

U.S. EPA Region 6 recommends use of benchmarks developed for the Texas Natural Resource Conservation Commission (TCEQ, 2001). These benchmarks are conservative screening level values intended to be protective of benthic biota. Values were compiled from a prioritized list of published values. The benchmark for PCBs is the Lowest Effects Levels (LELs) from Persaud et al. (1993).

FDEP TEL and PEL

Sources: Long, E.R. and L.G. Morgan 1990. *The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program.* NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, WA.

MacDonald, D.D. 1994. *Approach to the Assessment of Sediment Quality in Florida Coastal Waters.* Office of Water Policy, Florida Department of Environmental Protection, Tallahassee, Florida. (http://www.dep.state.fl.us/dwm/documents/sediment/volume1.pdf)

Sediment quality assessment guidelines developed for the State of Florida for 34 priority substances based on the approach recommended by Long and Morgan (1990). They are intended to assist sediment quality assessment applications, such as identifying priority areas for non-point source management actions, designing wetland restoration projects, and monitoring trends in environmental contamination. They are not intended to be used as sediment quality criteria.

NOAA ERL and ERM

Source: NOAA's National Status and Trends Program, *Effects range low (ERL) and effects range median (ERM) Sediment Quality Guidelines.* http://response.restoration.noaa.gov/cpr/sediment/SPQ.pdf

Ontario Low and Severe

Source: Persaud, D, R. Jaagumagi, and A. Hayton. 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.* Ontario Ministry of the Environment and Energy. August. ISBN 0-7729-9248-7. (Available at http://www.ene.gov.on.ca/envision/gp/B1_3.pdf)

OSWER

Source: U.S. Environmental Protection Agency. 1996b. *Ecotox thresholds*. ECO Update 3 (2):1-12. Office of Solid Waste and Emergency Response. (http://www.epa.gov/superfund/programs/risk/eco_updt.pdf)

5.1.2 Fish Tissue TRVs

Exposure of fish to potentially deleterious concentrations of PCBs is evaluated based on tissue residues. The U.S. Army Corps of Engineers/U.S. Environmental Protection Agency (2004) has established the Environmental Residue-Effects Database (ERED), which is a compilation of data, taken from the literature, where biological effects (e.g., reduced survival, growth, etc.) and tissue contaminant concentrations were simultaneously measured in the same organism. The database contains information on a broad range of biological effects caused by the presence of a particular contaminant in the tissue of an organism, from the induction of particular enzymes or enzyme systems to whole-organism effects on survival, growth, or reproduction. Currently, the database is limited to those instances where biological effects observed in an organism are linked to a specific contaminant within its tissues. This database was searched for PCB effects on fish. Effects concentrations for PCBs in whole body and fillet body parts are summarized in Appendix B. Both no effect TRVs and effect TRVs for fish exposure were selected from the ERED database based on the similarity of the test species and the target species for this site. For the bottomfeeder (i.e., omnivorous) species, the lowest whole body tissue concentration of 0.14 mg/kg PCBs in zebra danio *(Danio rerio)* was selected as the no effect TRV. This is the lowest no observed effect dose (NOED) for reproduction and mortality of the omnivorous test species. The lowest LOED for reproduction and mortality was 1.1 m/kg for the zebra danio and was selected as the effect TRV for the omnivorous bottomfeeders. For salmonid species, NOEDs range from 0.16 mg/kg for growth in juvenile chinook salmon *(Oncorhynchus tshawytscha)* to 81 mg/kg for growth and survival of juvenile rainbow trout (*Oncorhynchus mykiss*). The median of the ordered NOEDs (0.98 mg/kg for mortality of chinook salmon) juveniles was selected as the no effect TRV for predator (carnivorous) species. The LOED of 2.3 mg/kg for growth of coho salmon (*Oncorhynchus kisutch*) was used as the effect TRV for predator (carnivorous) species. In channel catfish fingerlings, a whole body tissue concentration of 2.172 mg/kg was the NOED for mortality while for immature catfish, the whole body tisse concentration of 14.3 was the LOED for growth. Since toxicity data was available for channel catfish, these values were used as the no effect TRV and the effect TRV for this species. TRVs for target fish species are summarized in Table 5-2

5.2 DERIVATION OF TRVs FOR BIRDS AND MAMMALS

TRVs presented in the form of an acceptable daily dose are based on field and laboratory tests for birds, mammals, or other organisms and indicate the absence or presence of adverse ecological impact. For example, daily doses for mammal species such as mice, rats, or dogs are readily available in the literature for many chemicals at levels often indicative of adverse effects. For chemical exposures, dose is expressed in mg-constituent/kg-body weight/day as an administered dose (mg/kg-bw/day). There are no U.S. EPA-established, acceptable daily doses for ecological receptors; therefore, dose-based TRVs were developed from the available scientific literature.

The derivation of toxicity reference values for the bird and mammal target receptors is based on the methodology outlined in the Review of the Navy - EPA Region 9 BTAG Toxicity Reference Values for Wildlife document as prepared for the U.S. Army Biological Technical Assistance Group and U.S. Army Corps of Engineers by CH2M Hill (2000). The BTAG has developed TRVs for mammals and birds for 20 chemicals, with the most recent recommended values presented in a 11/21/2002 revision. The no effect TRV is consistent with a chronic no-effect level; the no-effect level is the highest dose at which no effect to the test organism was observed. The effect TRV is consistent with a low effect level. An effect level is the dose at which a specific biological effect was seen in the laboratory test organism. Effect TRVs were selected from approximately the middle range of all sublethal effects for a particular chemical.

Allometric modeling from Sample and Arenal (1999) was used for interspecies extrapolations (when the test species is different from the wildlife or target receptor species). Body weights for test organisms were based on those from the actual test study whenever possible. When body weights were not available for the actual test species, then the weight of the same species from another study was used. The equation presented below was used to estimate the TRV for target bird and mammal species.

$$TRV_{wildlife\,species} = TRV_{test\,species}\left[\frac{BW_{test\,species}}{BW_{wildlife\,species}}\right]^{1-b}$$

where:

$TRV_{wildlife\ species}$ = TRV for target avian or mammalian wildlife species.
$TRV_{test\ species}$ = NOAEL for avian or mammalian test species.
$BW_{test\ species}$ = body weight of avian or mammalian test species.
$BW_{wildlife\ species}$ = body weight of avian or mammalian wildlife species.
b = allometric scaling factor that is specific to either birds or mammals.

Allometric scaling factors of 1.2 for birds and 0.94 for mammals were used (Sample and Arenal, 1999). TRVs for the bald eagle and the mink are summarized in Table 5-3.

Table 5-1
Sediment Screening Benchmarks
Manistique Harbor and River Site
Manistique, Michigan
All concentrations in mg/kg

			ARCS		Canadian		Consensus		FDEP		NOAA		OSWER	Ontario		EPA		
Analyte	CAS Number	NEC	PEC	TEC	ISQG	PEL	PEC	TEC	PEL	TEL	ERL	ERM	ET	Low	Severe	R4	R5 ESL	R6-FW
PCB-1016	12674112	-	-	-	-	-	-	-	-	-	-	-	-	0.007	0.53	-	-	0.007
PCB-1221	11104282	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-
PCB-1232	11141165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB-1242	53469219	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB-1248	12672296	-	-	-	-	-	-	-	-	-	-	-	-	0.03	1.5	-	-	0.03
PCB-1254	11097691	-	-	-	0.06	0.34	-	-	-	-	-	-	-	0.06	0.34	-	-	0.06
PCB-1260	11096825	-	-	-	-	-	-	-	-	-	-	-	-	0.005	0.24	-	-	0.005
PCBs (total)	1336363	0.194	0.24	0.03	0.0341	0.277	0.67	0.05	0.18	0.02	0.02	0.18	0.02	0.07	5.3	0.03	0.03	0.341

Source: ORNL RAIS, 2004.

NEC - No effect concentration
PEC - Probable effect concentration
TEC - Theshold effect concentration
ISQG - Interim sediment quality guideline
PEL - Probable effect level
TEL- Threshold effect level
ERL - Effects range low
ERM - Effect range median
ET - Effects threshold
ARCS - Assessment and Remediation of Contaminated Sediments
FDEP - Florida Department of Environmental Protection
NOAA - National Oceanic and Atmospheric Administration
EPA - U.S. Environmental Protection Agency
R4 - U.S. EPA Region 4
R5 ESL - EPA Region 5 ecological screening level
R6 FW - U.S. EPA Region 6 freshwater
OSWER - Office of Solid Waste and Emergency Response

Table 5-2
Toxicity Reference Values (TRVs) for PCBs for Target Fish Species
Manistique Harbor and River Site
Manistique, Michigan

Receptor Species	Test Species	Whole Body Wet Tissue Concentration (mg/kg)	Effect Class	Toxicity Measure	Species Feeding Behavior	Author
Channel catfish	Catfish-Channel	2.172	Mortality	NOED	Omnivore	Hansen LG, WB Wiekhurst, J Simon, 1976
	Catfish-Channel	14.3	Growth	LOED	Omnivore	Hansen, L.G., W.B. Wiekhorst and J. Simon, 1998
White sucker/shorthead redhorse/longnose sucker	Zebra Danio	0.14	Mortality/Reproduction	NOED	Not Specified	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L. Norrgren, 1998
	Zebra Danio	1.1	Reproduction	LOED	Not Specified	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L. Norrgren, 1998
Walleye/smallmouth bass	Salmon-coho	2.3	Growth	LOED	Carnivore-aquatic insects, fish, inverts	Gruger, E.H., T. Hurley and N.L. Karrick, 1976
	Salmon - Chinook	0.98	Mortality	NOED	Carnivore-aquatic insects, fish, inverts	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen, 2003

Source: ERED database; see Table B-1.

TABLE 5-3
TOXICITY REFERENCE VALUES (TRVs) FOR BALD EAGLE AND MINK
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

COEC	Test Species	Test Species Chronic NOAEL Dose (mg/kg/day)		Test Species Chronic LOAEL Dose (mg/kg/day)		Toxic Endpoint	Test Species Body Weight (kg)	Body Weight Reference	Target Wildlife Species -No Effect TRV (mg/kg/day)	Target Wildlife Species - Effect TRV (mg/kg/day)
TOXICITY REFERENCE VALUE (TRV) CALCULATIONS FOR BALD EAGLE										
PCBs	Chicken	9.00E-02	c	1.27E+00	c	Reproductive	1.50E+00	U.S. EPA (1988)	1.13E-01	1.59E+00
Aroclor 1248	Screech Owl	4.10E-01	e	4.10E+00	f	Reproduction	1.81E-01	Dunning (1984)	7.83E-01	7.83E+00
Aroclor 1254	Ring-necked Pheasant	1.80E-01	a	1.80E+00	a	Reproduction	1.00E+00	U.S. EPA (1993a)	2.44E-01	2.44E+00
Aroclor 1260	Ring-necked Pheasant	1.80E-01	b	1.80E+00	b	Reproduction	1.00E+00	U.S. EPA (1993a)	2.44E-01	2.44E+00
TOXICITY REFERENCE VALUE (TRV) CALCULATIONS FOR MINK										
PCBs	Mink	5.00E-02	d	1.00E-01	d	Reproductive	8.00E-01	U.S. EPA 1995c	5.00E-02	1.00E-01
Aroclor 1242	Mink	6.90E-02	a	6.90E-01	a	Reproduction	8.00E-01	U.S. EPA 1995c	6.90E-02	6.90E-01
Aroclor 1254	Mink	1.40E-01	a	6.90E-01	a	Reproduction	8.00E-01	U.S. EPA 1995c	1.40E-01	6.90E-01
Aroclor 1260	Mink	1.40E-01	b	6.90E-01	b	Reproduction	8.00E-01	U.S. EPA 1995c	1.40E-01	6.90E-01

Target Species:	Body Weights:	Units:	Weight References:
Bald eagle	4.6	kg	U.S. EPA 1995c
Mink	0.8	kg	U.S. EPA 1995c

Acronyms:
COEC = Constituent of ecological concern
LOAEL = Lowest Observed Adverse Effect Level
NOAEL = No Observed Adverse Effect Level

Target Avian Species TRV = $TRV_{test\ species} * (BW_{test\ species}/BW_{target\ species})^{1-1.2}$
Target Mammal TRV = $TRV_{test\ species} * (BW_{test\ species}/BW_{target\ species})^{1-0.94}$
Reference: Sample and Arenal, 1999.
No body weight adjustment was performed when the test species is the same as the target wildlife species (i.e., for mink)

Notes:
a = TRVs for test species obtained from ORNL's *Toxicological Benchmarks for Wildlife: 1996 Revision*. ES/ER/TM-86/R3.
b = TRV based on Aroclor-1254 as a surrogate.
c = U.S. EPA Region 9 Biological Technical Assistance Group (BTAG) Recommended Toxicity Reference Values for Birds (Revision Date 11/21/2002).
d = Based on TRVs used in Fox River ERA (The Retec Group, 2002.).
e = McLane, M. and D. Hughes. 1980. Reproductive success of Screech owls fed Aroclor 1248. *Arch. Environ. Contam. Toxicol.* 9:661-665.
f = A LOAEL was not available; the NOAEL was extrapolated to a LOAEL by multiplying by a factor of 10.

References:
Dunning, 1984. *Body weights of 686 species of North American birds*. West. Bird Banding Assoc. Monogr. No. 1. Eldon Publ. Co. Cave Crk, AZ. 38 pp.
U.S. EPA, 1988. *Recommendations for and Documentation of Biological Values for Use in Risk Assessment.*
U.S. EPA, 1993a. *Great Lakes water quality initiative criteria documents for the protection of wildlife (proposed): DDT, Mercury, 2,3,7,8-TCDD, PCBs*. EPA/822/R-93-007.
Office Science and Technology, Washington, D.C.
U.S. EPA, 1995c. Final Water Quality Guidance for the Great Lakes System, 40 CFR Parts 9, 122, 123, 131and 132, 23 March 1995.
Sample, B.E., and C.A. Arenal. 1999. *Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data*. Bull. Environ. Contam. Toxicol. 62:653-663.
The Retec Group. 2002. *Final Baseline Human Health and Ecological Risk Assessment. Lower Fox River and Green Bay, Wisconsin. Remedial Investigation and Feasibility Study.*
Prepared for Wisconsin Department of Natural Resources. December 2002.

SECTION 6

RISK CHARACTERIZATION

The risk characterization integrates the information from the problem formulation and the exposure and ecological effects characterizations to estimate the nature and extent of potential ecological risk. The ecological risk characterization for this assessment is based on the hazard quotient (HQ) method as summarized below.

6.1 HAZARD QUOTIENT METHOD

The hazard quotient (HQ) method is used as an indicator of the risks posed to surrogate ecological receptors from exposure to site-related contaminants (U.S. EPA, 1996c). The hazard quotient compares exposure values to TRVs, and can be expressed as the ratio of a potential exposure level to the TRV:

$$HQ = \frac{Exposure}{TRV}$$

where:

Exposure = Exposure concentration at the exposure point (e.g., mg-contaminant/kg-sediment) or the estimated contaminant dose at the exposure point (mg/kg-bw/day).

TRV = Toxicity reference value, i.e., effect dose or effect criteria (in units that match the exposure concentration or exposure dose)

If the calculated HQ exceeds unity (i.e., >1), then it simply indicates that the target receptor may be at risk to an adverse effect from that chemical through that exposure route. Because TRVs incorporate a number of extrapolation factors, if a TRV is exceeded (meaning the HQ exceeds unity), it does not necessarily indicate that an adverse effect will occur. Further evaluation may be needed for those chemicals with a HQ that exceeds one. HQs were calculated for both the no effect TRV and effect TRV.

Exposures to the same chemical through multiple exposure routes (e.g., ingestion of sediment and tissue) or mediums were conservatively assumed to be additive. Consequently, a HQ for a specific chemical examines the potential for risk posed by that chemical through more than one exposure route or medium. The HQ is an expression of the additivity of non-carcinogenic health effects. For example, the HQ for an individual chemical over several media and routes of exposure is determined for a receptor as follows:

$$HQ_{chemical} = HQ_{route\ 1} + HQ_{route\ 2} + HQ_{route\ 3} + \ldots\ldots HQ_{route\ n}$$

Where:

$HQ_{chemical}$	=	Hazard quotient for a specific chemical.
$HQ_{route\ 1}$	=	Hazard quotient for the same chemical through exposure route 1.
$HQ_{route\ 2}$	=	Hazard quotient for the same chemical through exposure route 2.
$HQ_{route\ 3}$	=	Hazard quotient for the same chemical through exposure route 3.

For benthic organisms, the range of sediment benchmarks was used as TRVs to calculate HQs. For fish, both NOEDs and LOEDs were used as no effect TRVs and effect TRVs to calculate HQs. For the food web modeling, HQs were calculated for both the no effect TRV and the effect TRV.

6.2 SUMMARY OF RESULTS

Aquatic organisms may be exposed to PCBs directly or through the food chain. The potential risk to the target ecological receptors is characterized in this subsection.

6.2.1 Benthic Organisms

To assess the potential for adverse effects on benthic organisms from exposure to potentially toxic sediment, the range of detected sediment concentrations in the Manistique Harbor and River were compared to sediment screening benchmarks (Table 6-1). The average concentration of PCBs did not exceed the highest benchmark (i.e., Ontario severe effects levels), but the average concentration did exceed the threshold concentrations (i.e., ARCS TEC and Consensus TEC). While these results show a potential for adverse impacts to benthic organisms from sediment exposure, these risks may be localized at particular "hotspots", rather than distributed throughout the harbor and river.

6.2.2 Fish

Exposure of fish to potentially deleterious concentrations of PCBs is evaluated based a comparison of tissue residues to residue effects concentrations (Table 6-2). The mean and 95UCL concentration of total PCBs in the whole body fish tissue for the target species collected from the Manistique Harbor and River were compared to tissue NOEDs and LOEDs for similar fish species. For the bottomdweller (i.e., omnivorous) fish species, the HQs range from 0.017 to 6.9. The HQ exceeded one for the sucker species but not for the channel catfish. The HQs based on the LOED and the 95 UCL tissue concentration did not exceed one any of the bottomfeeder species. For the predator (i.e., carnivorous) fish species, the HQs range from 0.07 to 0.6. For the predatory fish species, the HQs were less than 1.0 and therefore indicate no risk.

6.2.3 Bald Eagle

The bald eagle may be exposed to PCBs through ingestion of fish and incidental ingestion of sediment. The estimated daily dose and the potential risk to the bald eagle are presented in Table 6-3. The HQ based on the no effect TRV was 0.51 for total PCBs and the HQ based on the effect TRV was 0.036 for total PCBs. All HQs for the individual Aroclors were less than 1. These HQs were less than one and therefore indicate no risk.

6.2.4 Mink

The mink may be exposed to PCBs through ingestion of fish and incidental ingestion of sediment. The estimated daily dose and the potential risk to a mink are presented in Table 6-4. The HQ based on the no effect TRV was 1.2 for total PCBs and the HQ based on the effect TRV was 0.6 for total PCBs. For Aroclor 1248, the HQ based on the no effect TRV was 1 and the HQ based on the effect

TRV was 0.1. The HQs based on the no effect TRV exceeded one for the total PCBs indicating potential risk. However, the HQs based on the effect TRV for total PCBs and for the individual Aroclors were less than 1, suggesting that this potential risk is limited.

6.3 UNCERTAINTY

Virtually every step in the risk assessment process requires numerous assumptions, all of which contribute to uncertainty in the risk evaluation. The objectives of this uncertainty section are to:

- Provide to the appropriate decision makers a summary of those factors that significantly influence the risk results, evaluate their range of variability, and assess the contribution of these factors to the under- or overestimation of risk.
- Discuss the data underlying the assumptions that most significantly influenced the risk to highlight the strengths and weaknesses of the risk assessment results.

General and site-specific uncertainties in this ERA are discussed in the following subsections.

6.3.1 Uncertainty Associated With Data Evaluation and Reduction

Following is a discussion of uncertainties related to data evaluation and reduction.

- Various types of data qualifiers are attached to analytical data by either the laboratory conducting the analyses or by the person performing data validation. A common data qualifier in data packages is the "J" qualifier. Data qualified with a J are estimated concentrations reported below the sample quantitation limit (SQL), but exceed the method detection limit (MDL). The concentration is considered an estimated value. In this ERA, estimated data were used the same way as positive data detected above the SQL. Sometimes, a level of bias is associated with the estimated data, indicating whether the concentration is biased high or low. Other times, the level of bias is unknown. The use of estimated data as the reported concentration may result in either an under- or overestimation of the actual concentration.

- The data set for a particular chemical generally will contain some samples with positive results and others with non-detect results. The non-detect results in this ERA have been included at one-half the SQL in the calculation of the 95% UCL. The SQL represents the lowest value at which the element or compound may be positively identified in a sample preparation. The chemical may be present at a concentration just below the SQL, or it may not be present in the sample at all. Including sample non-detects at one-half the SQL limit in the calculation of the 95% UCL may result in an underestimation or overestimation of the actual exposure concentration.

6.3.2 Uncertainty Associated With Problem Formulation and Characterization of Exposure

Following is a discussion of uncertainties related to problem formulation and exposure characterization.

- Conceptual model development may account for one of the most important sources of uncertainty in a risk assessment. If important relationships are missed or specified incorrectly, the risk characterization may misrepresent actual risks. The conceptual model developed for the Harbor and River includes those groups of species and feeding guild expected to be maximally exposed to PCBs in an aquatic environment (i.e., piscivores). Although some species were not evaluated directly, the potential for risk to those species was not expected to be greater than those evaluated.

- The EPC used in risk assessments to estimate exposure intakes should be based on the arithmetic average concentration for a contaminant based on a set of site sampling results (U.S. EPA, 1997). Because of the uncertainty associated with estimating the true average concentration at a site, the 95% UCL of the arithmetic mean is used in risk assessments as a conservative estimate of the average concentration. The 95% UCL provides reasonable confidence that the true site average will not be underestimated. EPCs for sediment and fish tissue were based on the 95% UCL of the arithmetic mean. Note, the maximum detected concentration was selected to estimate the EPC if its concentration was less than the 95% UCL concentration.

- For each target wildlife receptor, site use factor (SUF) and dietary composition factors (DCF) were conservatively assumed to be 100%. The use of 100% for these factors assumes that the target wildlife species forages for all of its food, all year round, from the harbor and river. These assumptions are very conservative considering the home ranges the mink and bald eagle. In addition, the receptor species may be foraging on other food sources and food types aside from fish in the Harbor and River, therefore the DCF would be less than 100%. As a result, use of 100% for the aforementioned factors will contribute to an overestimation of risk.

- Ingestion of sediment by the mink and bald eagle is negligible. In addition, most sediment within the Harbor and River would be inaccessible due to the water depth. Thus, including sediment exposure for these receptors results in an overestimation of risk.

- The bioavailability of PCBs in the environmental media and diet of the receptors (e.g., sediment and tissue) was estimated at 100%. In other words, 100% of the concentration of a detected chemical was assumed available for toxicity. In this ERA, bioavailability of PCBs was assumed to be similar to that observed in the toxicity studies reported in the literature. Thus, toxicity may be over- or underestimated, depending in part on the extent to which site-specific compound bioavailability differs from those in studies reported in the literature.

- Historical activities, including sawmill operations and routine dredging, have severely altered the substrate available for the colonization of the river and harbor (Terra Inc., 1994). The substrate in the Manistique River and Harbor includes an accumulation of sawdust and wood chips from sawmills. Grain size analysis of the sediments indicate that they are primarily fine sands, with some silty fine sands. The organic carbon content in the fine sands is low, about 0.1 percent, though higher organic carbon contents (> 1% to 38.6%) were measured in samples with sawdust and leaves. Thus, the substrate provided by the harbor and river is not expected to provide the habitat needed for a thriving benthic community.

6.3.3 Uncertainty Associated With Characterization of Effects

Toxicity of a contaminant is assessed by identifying TRVs in the literature specific to the contaminant and the measurement receptor being evaluated. The following is a discussion of the uncertainties associated with the TRVs.

- The TRVs used in risk characterization of this ERA for upper trophic level class-specific guilds (i.e., mink and bald eagle) are provided in terms of dose ingested (mg/kg/day) and are based on laboratory studies. The no effect TRV is consistent with a chronic no-effect level; the no-effect level is the highest dose at which no effect to the test organism was observed. The effect TRV is consistent with a low effect level. An effect level is the dose at which a specific biological effect was seen in the laboratory test organism. Effect TRVs were selected from approximately the middle range of all sublethal effects for a particular chemical. Suter and others have evaluated data sets from multiple taxonomic groups to derive regressions or distributions describing how the endpoints for different taxa might vary (Suter, 1993). Uncertainties associated with the derivation of wildlife TRV based on data on laboratory animals is provided below (Sample, 1996).

- Variations in physiological or biochemical factors may exist among species; these factors may include uptake, metabolism, and disposition, which can alter the potential toxicity of a contaminant to a particular species.

- Inbred laboratory strains may have an unusual sensitivity or resistance to the tested compound. Behavioral and ecological parameters (e.g., stress factors such as competition, seasonal changes in temperature or food availability, diseased states, or exposure to other contaminants) may make a wildlife species' sensitivity to an environmental contaminant different from that of a laboratory or domestic species.

- Available studies on wildlife or laboratory species may not include evaluations of all significant endpoints for determining long-term effects on natural populations. Important data that may be lacking are potential effects on reproduction, development, and population dynamics following multi-generation exposures.

- If fewer steps are involved in the extrapolation process, then the uncertainty in estimating the wildlife NOAEL is lower. For example, extrapolating from a NOAEL for an appropriate toxic endpoint (i.e., reproductive or population effects) for white laboratory mice (i.e., test species) to white-footed mice (i.e., target wildlife species) that are relatively closely related and of comparable body size would have a high level of reliability. Conversely, extrapolating from a LOAEL for organ-specific toxicity (e.g., liver or kidney damage) in laboratory mice to a non-rodent wildlife species such as mink would have a low level of reliability in predicting population effects among these species.

- Chronic TRVs for the eagle were adjusted to the target species using allometric methods. No allometric scaling was done for the mink TRVs since the test species is the same as the target receptor species. The allometric method approach incorporates the use of body scaling parameters (i.e., body weight) to estimate a toxic concentration for a class of organisms (e.g., the toxic dose to birds). There is uncertainty associated with applying a default scaling coefficient, and the applicability of allometric coefficients based on an acute toxicity data to chronic toxicity data is unknown (Sample and Arenal, 1999). Reviews on allometric scaling caution that there are several conditions that need to be met to apply allometric scaling with confidence. For example:

- "[T]he allometric approach is the method of choice [for controlling plasma concentrations of a drug] and can be applied to the data, provided that the pharmacokinetics are first order in each species, the percentage of protein binding is similar and linear over the concentration range of interest, the elimination processes are physical (i.e., renal or biliary), and enough data are available for satisfactory linear regression." (Mordenti, 1986).

- "There is no guarantee that the allometric approach will work. Several reasons for the failure of the allometric equation to describe some data include (1) species differences in binding and metabolic pathways, (2) species differences in target cell sensitivity, (3) schedule dependency due to exposure time differences, and (4) laboratory differences..... When the metabolism produces active metabolites, the factors considered for the allometric model are not, in many cases, relevant. Indeed, it could be argued that the faster metabolism often associated with small animals will make them more vulnerable... because of the relatively higher production of toxic metabolites" (Mordenti and Chappell, 1989).

- "[A]mbiguous results can arise in the allometric when the body weights used of interspecies allometric predictions are not broad, defined, or specified. Any extrapolation outside the range of experimental body size could cause intrinsic errors. This is because these allometric regressions are empirically determined and apply only to the sizes within the ranges of the original data...On the other hand, when the allometric relationship is applied to a narrow range of animal sizes, the power model is less appropriate than the linear model.. Other problems of the allometric prediction arise from statistical complications. First, the potential transformation bias will reduce the quality of prediction." (Wen et al., 1990).

- The Environmental Residue-Effects Database (ERED) is a compilation of data, taken from the literature, where biological effects (e.g., reduced survival, growth, etc.) and tissue contaminant concentrations were simultaneously measured in the same organism. Except for the channel catfish, residue-effects data was not available for the target species collected from the Harbor and River. For the omnivorous bottomdwelling species (except the channel catfish), the TRV is based on the zebra danio, an omnivorous species with the lowest NOED and LOED concentrations of all the species listed in the database for PCBs. The highest 95UCL total PCB concentration for the sucker species (2.01 mg/kg) does not exceed the NOED for the channel catfish (2.172 mg/kg). In addition, it is well known that the tissue concentration of a lipophilic toxicant causing the response is directly related to the amount of lipid in an organism. The higher the lipid content, the higher the resistance to the toxicant because a higher proportion of the hydrophobic compound is associated with the lipid and is not available to cause toxicity (Meador et al., 2002;

Geyer et al., 1993 and 1994). In contrast, lipid levels positively correlate with bioaccumulation and the half-life of absorbed contaminants in receptor species (Geyer et al., 1997). Thus, while receptors with high lipid content will both absorb and retain chemicals to a greater extent, there is potential for increased risk to predators consuming prey with high lipid contents. The average measured lipid contents in the sucker species ranged from 6.1 to 9.9 percent. Thus, use of effects data for a small cyprinid species to represent effects on larger bottomdwelling species may result in an overestimation of risk to the bottomdwelling species.

6.4 RISK DESCRIPTION

Overall, the HQ analysis indicates that exposure to PCBs by piscivorous birds and mammals poses little to no risk to the eagle and the mink. The HQ analysis indicates potentially unacceptable levels of risk to benthic organisms and bottomdwelling species. However, the substrate provided by the Harbor and River is not expected to support a thriving benthic community. The highest tissue residue concentrations were measured in bottomdwelling species, which have high lipid contents. The higher the lipid content, the higher the resistance to the toxicant. Since there is a potential for adverse effects on benthic organisms and fish, continued monitoring of sediment and fish tissue is recommended.

Table 6-1
Sediment Hazard Quotients
Manistique Harbor and River Site
Manistique, Michigan
All concentrations in mg/kg

Analyte	PCB Concentration		Screening Benchmark			Hazard Quotient: Mean Concentration			Hazard Quotient: 95UCL Concentration		
	Mean	95UCL									
ARCS			NEC	PEC	TEC	NEC	PEC	TEC	NEC	PEC	TEC
PCBs (total)	0.74	1.696	0.194	0.24	0.03	3.8	3.1	25	8.7	7.1	57
Canadian			ISQG	PEL		ISQG	PEL		ISQG	PEL	
PCB-1254	0.19	0.464	0.06	0.34		3.2	0.56		7.7	1.4	
PCBs (total)	0.74	1.696	0.034	0.277		21.7	2.67		50	6.1	
Consensus			PEC	TEC		PEC	TEC		PEC	TEC	
PCBs (total)	0.74	1.696	0.67	0.05		1.1	15		2.5	34	
FDEP			PEL	TEL		PEL	TEL		PEL	TEL	
PCBs (total)	0.74	1.696	0.18	0.02		4.1	37		9.4	85	
NOAA			ERL	ERM		ERL	ERM		ERL	ERM	
PCBs (total)	0.74	1.696	0.02	0.18		37	4.1		85	9.4	
OSWER			ET			ET			ET		
PCBs (total)	0.74	1.696	0.02			37			85		
Ontario			Low	Severe		Low	Severe		Low	Severe	
PCB-1248	0.55	1.432	0.03	1.5		18	0.37		48	0.95	
PCB-1254	0.19	0.464	0.06	0.34		3	0.56		7.7	1.4	
PCB-1260	0.133	0.298	0.005	0.24		27	0.55		60	1.24	
PCBs (total)	0.74	1.696	0.07	5.3		11	0.14		24	0.32	
EPA			R4	R5 ESL	R6-FW	R4	R5 ESL	R6-FW	R4	R5 ESL	R6-FW
PCB-1248	0.55	1.432	-	-	0.03	-	-	18	-	-	48
PCB-1254	0.19	0.464	-	-	0.06	-	-	3.2	-	-	7.7
PCB-1260	0.133	0.298	-	-	0.005	-	-	27	-	-	60
PCBs (total)	0.74	1.696	0.03	0.03	0.341	25	25	2.2	57	57	5.0

See Table 5-1 for references for sediment benchmark values.
95UCL = 95% upper confidence limit

TABLE 6-2
Hazard Quotients for Whole Fish
Manistique Harbor and River Site
Manistique, Michigan

Species	Analyte	Detected Samples	PCB Concentrations				Fish TRV		Hazard Quotient: NOED		Hazard Quotient: LOED	
			Minimum	Maximum	Mean*	95 UCL	NOED	LOED	Mean	95 UCL	Mean	95 UCL
ADULT FISH TISSUE												
Bottomfeeders (omnivores)												
White Sucker	Total PCBs	6/8	0.04	1.16	0.371	0.62	0.14	1.1	2.7	4.4	0.3	0.6
Shorthead Redhorse	Total PCBs	4/4	0.14	1.06	0.453	0.96	0.14	1.1	3.2	6.9	0.4	0.9
Longnose Sucker	Total PCBs	1/1	0.46	--	0.46	0.46	0.14	1.1	3.3	3.3	0.42	0.42
Channel Catfish	Total PCBs	1/1	0.25	--	0.25	0.25	2.172	14.3	0.1	0.1	0.017	0.017
Predators (carnivores)												
Walleye	Total PCBs	10/15	0.05	0.43	0.161	0.231	0.98	2.3	0.2	0.2	0.070	0.100
Smallmouth Bass	Total PCBs	2/2	0.07	0.61	0.34	0.61	0.98	2.3	0.3	0.6	0.148	0.265
YEARLING FISH TISSUE												
Walleye	Total PCBs	2/4	0.14	0.199	0.1695	0.199	0.98	2.3	0.2	0.2	0.074	0.087

NA - Not available.
All fish tissue presented on a wet weight basis.
All concentrations in mg/kg
PCBs were not detected in bottomfeeder yearling fish tissue
95 UCL = 95 percent upper confidence limit.
If a 95UCL could not be calculated, the maximum detected concentration is presented.

TABLE 6-3
BALD EAGLE RISK CALCULATIONS
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

COPEC	Exposure Point Concentrations			Sediment Ingestion	Tissue Ingestion	Total Ingestion	No Effect TRV[3] (mg/kg/day)	Hazard Quotient - No Effect				Effect TRV[3] (mg/kg/day)	Hazard Quotient - Effect			
	Sediment (dry wt)	TL-3 Tissue[2]	TL-4 Tissue[2]	Intake (mg/kg/day)	Intake (mg/kg/day)	Intake (mg/kg/day)		Sediment	Tissue	Total			Sediment	Tissue	Total	
Aroclor 1248	0	340	61	0.00E+00	2.96E-02	2.96E-02	7.83E-01	0.00E+00	3.78E-02	3.78E-02	<1	7.83E+00	0.00E+00	3.78E-03	3.78E-03	<1
Aroclor 1254	0.752	256	130	1.84E-04	2.40E-02	2.42E-02	2.44E-01	7.53E-04	9.84E-02	9.91E-02	<1	2.44E+00	7.53E-05	9.84E-03	9.91E-03	<1
Aroclor 1260	0.140	79	89	3.42E-05	8.43E-03	8.47E-03	2.44E-01	1.40E-04	3.45E-02	3.47E-02	<1	2.44E+00	1.40E-05	3.45E-03	3.47E-03	<1
							HQ-No Effect	8.93E-04	1.71E-01	1.72E-01	<1	HQ-Low Effect	8.93E-05	1.71E-02	1.72E-02	<1
PCBs	0.798	621	270	1.95E-04	5.73E-02	5.75E-02	1.13E-01	1.73E-03	5.07E-01	5.09E-01	<1	1.59E+00	1.23E-04	3.61E-02	3.62E-02	<1

Notes:
<1 = Chemical has a hazard quotient that is less than one.
NA = Not Applicable
TRV = Toxicity Reference Value
HQ = Hazard Quotient
[1] EPCs for surface sediment are presented in Table 4-1.
[2] Tissue EPCs are based on the 95UCL wet weight concentration detected in fish (Table 4-1).
[3] TRVs derived for the eagle are presented in Table 5-3. TRV for Aroclor 1242 is based on TRV for Aroclor 1248.

Exposure Assumptions and Equation:

	Value	Units	
IRtissue[a] =	0.47883	kg/day-wet wt	
IRtissue[a] =	0.1125	kg/day-dry wt	IRtissue (dry wt.) = IRtissue (wet wt.)*(1-tissue moisture)
IRTL4 tissue[b] =	0.09573	kg/day-wet wt	
IRTL3 tissue[c] =	0.38310	kg/day-wet wt	Eagle Intake Equation (Sediment) = ((CF x Csed) x IRsed dry wt x SUF x DCF) / BW
IRsed[a] =	0.001125	kg/day-dry wt	
Ctissue =	chem-specific	ug/kg-wet wt	Eagle Intake Equation (Tissue) = ([(OCF x CTL3tissue) x IR TL3 tissue-TL3] + [(OCF x CTL3tissue) x IR TL3 tissue-TL3] x SUF x DCF) / BW
Csed =	chem-specific	mg/kg-dry wt	
Tissue moisture[d]	76.5%	percent	HQ = Intake/TRV
Dietary Composition Factor (DCF)[e]	100%		
Site Use Factor (SUF)[f] =	100%		
Organics Conversion Factor (OCF) =	1.E-03	mg/μg	
Body Weight (BW) =	4.60	kg	

a The tissue ingestion rate is based in wet weight. Sediment ingestion rate conservatively assumed to be 1% of food ingestion rate.
b Sum of FB and TL4 ingestion rates; See Table 4-2
c Sum of TL3 and other ingestion rates; See Table 4-2
d Average value for all bottomfeeder or predator species; See Table 4-2
e Dietary composition factor was based on a conservative assumption of 100% fish from the harbor.
f Site use factor was based on a conservative 100% use of the river and harbor for the eagle's foraging range.

TABLE 6-4
MINK RISK CALCULATIONS
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

COPEC	Exposure Point Concentrations[1]			Sediment Ingestion	Tissue Ingestion	Total Ingestion	No Effect TRV[3] (mg/kg/day)	Hazard Quotient - No Effect			Effect TRV[3] (mg/kg/day)	Hazard Quotient - Effect		
	Sediment (dry wt)	TL-3 Tissue[2]	TL-4 Tissue[2]	Intake (mg/kg/day)	Intake (mg/kg/day)	Intake (mg/kg/day)		Sediment	Tissue	Total		Sediment	Tissue	Total
Aroclor 1248	0	340	61	0.00E+00	6.89E-02	6.89E-02	6.90E-02	0.0E+00	1.0E+00	1.0E+00 <1	6.90E-01	0.0E+00	1.0E-01	1.0E-01 <1
Aroclor 1254	0.752	256	130	3.90E-04	2.87E-02	2.91E-02	1.40E-01	2.8E-03	2.1E-01	2.1E-01 <1	6.90E-01	5.7E-04	4.2E-02	4.2E-02 <1
Aroclor 1260	0.140	79	89	7.27E-05	1.97E-02	1.97E-02	1.40E-01	5.2E-04	1.4E-01	1.4E-01 <1	6.90E-01	1.1E-04	2.8E-02	2.9E-02 <1
							HQ-No Effect	3.3E-03	1.3E+00	1.3E+00	HQ-Low Effect	6.7E-04	1.7E-01	1.7E-01 <1
PCBs	0.798	621	270	4.14E-04	5.96E-02	6.01E-02	5.00E-02	8.3E-03	1.2E+00	1.2E+00	1.00E-01	4.1E-03	6.0E-01	6.0E-01 <1

Notes:
<1 = Chemical has a hazard quotient that is less than one.
NA = Not Applicable
TRV = Toxicity Reference Value
HQ = Hazard Quotient
[1] EPCs for surface sediment are presented in Table 4-1.
[2] Tissue EPCs are based on the 95UCL wet weight concentration detected in fish (Table 4-1).
[3] TRVs derived for the mink are presented in Table 5-3.

Exposure Assumptions and Equation:

	Value	Units	
IRtissue[a] =	0.1767	kg/day-wet wt	
IRtissue[a] =	0.0415	kg/day-dry wt	IRtissue (dry wt.) = IRtissue (wet wt.)*(1-tissue moisture)
IRTL4 tissue[b] =	0.0177	kg/day-wet wt	
IRTL3 tissue[c] =	0.15900	kg/day-wet wt	Mink Intake Equation (Sediment) = ((CF x Csed) x IRsed dry wt x SUF x DCF) / BW
IRsed[a] =	0.000415	kg/day-dry wt	
Ctissue =	chem-specific	mg/kg-wet wt	Mink Intake Equation (Tissue) = {[(OCF x CTL3tissue) x IR TL3 tissue-TL3] + [(OCF x CTL3tissue) x IR TL3 tissue-TL3] x SUF x DCF} / BW
Csed =	chem-specific	mg/kg-dry wt	
Tissue moisture[d]	76.5%	percent	HQ = Intake/TRV
Dietary Composition Factor (DCF)[e] =	100%		
Site Use Factor (SUF)[f] =	100%		
Organics Conversion Factor (OCF) =	1.E-03	mg/µg	
Body Weight (BW) =	0.80	kg	

a The tissue ingestion rate is based in wet weight. Sediment ingestion rate conservatively assumed to be 1% of food ingestion rate.
b Based on other ingestion rate; See Table 4-2
c TL3 ingestion rate; See Table 4-2
d Average value for all species; See Table 4-2
e Dietary composition factor was based on a conservative assumption of 100% fish from the harbor.
f Site use factor was based on a conservative 100% use of the river and harbor for the mink's foraging range.

SECTION 7

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APPENDIX A

Analytical Data Tables

TABLE A-1
FISH TISSUE DATA (WHOLE BODY)
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

				Tissue Concentration						
Sample ID	**Species**	**Area**	**Age**	**Aroclor 1248**	**Aroclor 1254**	**Aroclor 1260**	**Total PCB ****	**% Lipid - C**	**% Lipid - F**	**% Moisture**
Adult Predator Species										
MH1-AF01	WALLEYE	River	2+	0.13	0.07	< 0.099	0.17	1	0.6	
MH1-AF02	WALLEYE	River	2+	< 0.099	0.19	< 0.099	0.19	4.6	1.3	
MH1-AF03	WALLEYE	River	2+	0.09	0.07	0.04	0.09	2.6	1.3	
MH1-AF04	WALLEYE	River	3+	0.09	0.23	0.11	0.39	3.7	0.5	
MH1-AF05	WALLEYE	River	2+	< 0.099	0.07	< 0.099	0.07	4	0.3	
MH1-AF08	WALLEYE	River	2+	< 0.099	< 0.099	0.19	0.19	6.7	0.7	
MH1-AF14	WALLEYE	River	3+	< 0.099	0.11	0.05	0.14	5.4	0.35	81.5 F
MH1-AF18	WALLEYE	River	2+	< 0.099	0.09	0.13	0.13	5.9	0.4	
MH1-AF19	WALLEYE	River	2+	< 0.099	< 0.099	0.05	0.05	–	1.5	
MH1-AF21	WALLEYE	River	2+	< 0.099	0.09	< 0.099	0.09	–	–	79.3 F
MH1-AF22	WALLEYE	River	3+	< 0.099	0.06	0.06	0.06	–	–	
MH1-AF24	SMALLMOUTH BASS	River	4+	0.06	< 0.099	0.06	0.07	–	1.6	77 F
MH1-AF27	WALLEYE	River	3+	< 0.099	0.29	0.16	0.43	11.4	–	
MH1-AF28	SMALLMOUTH BASS	River	4+	< 0.099	0.44	0.19	0.61	13.8	1.6	
MH1-AF29	WALLEYE	River	3+	< 0.099	0.09	0.09	0.09	4.23	1.59	
Adult Bottomfeeder Species										
MH1-AF06	WHITE SUCKER	River	6+	0.54	0.51	0.13	1.16	3.8	1.9	
MH1-AF10	WHITE SUCKER	River	4+	0.34	0.18	0.04	0.54	7.9	1	79.3 F
MH1-AF12	WHITE SUCKER	Inner Harbor	9+	0.099 U	0.099 U	0.04	0.04	3.4	0.6	62.5 C; 77.9 F
MH1-AF15	WHITE SUCKER	River	8+	0.18	0.22	0.08	0.44	4.7	1	80.8 F
MH1-AF16	WHITE SUCKER	River	3+	0.17	0.10	0.04	0.27	5.4	0.7	79.2 F
MH1-AF17	WHITE SUCKER	River	3+	0.099 U	0.25	0.09	0.32	5.3	1	
MH1-AF23	WHITE SUCKER	River	3+	0.14	0.099 U	0.04	0.16	–	–	
MH1-AF26	WHITE SUCKER	River	3+	0.099 U	0.099 U	0.04	0.04	–	–	
MH1-AF07	SHORTHEAD REDHORSE	River	4+	0.09	0.10	0.099 U	0.15	8.2	2	
MH1-AF09	SHORTHEAD REDHORSE	River	3+	0.71	0.33	0.05	1.06	7.4	2.8	
MH1-AF13	SHORTHEAD REDHORSE	Inner Harbor	8+	0.33	0.14	0.05	0.46	6.1	3.3	69.3 F
MH1-AF20	SHORTHEAD REDHORSE*	River	7+	0.14	0.04	0.099 U	0.14	–	2.7	77.6 F
MH1-AF25	LONGNOSE SUCKER	River	7+	0.22	0.20	0.08	0.46	–	–	77.7 F
MH1-AF11	CHANNEL CATFISH	Inner Harbor	11+	0.099 U	0.15	0.12	0.25	9.6	4.7	74.9 F
Yearling Fish										
Yearling Predator Species										
MH1-FY01	WALLEYE	River	Y	< 0.099	0.16 J	0.039 J	0.199		2.9	
MH1-FY02	ROCK BASS	Harbor	Y	< 0.099	< 0.099	< 0.099	ND			71.7
MH1-YF04	WALLEYE	River	Y	< 0.099	0.14	< 0.099	0.14		2.7	
MH1-YF05	SMALLMOUTH BASS	River	Y	< 0.099	< 0.099	< 0.099	ND		3.1	
Yearling Bottomfeeder Species										
MH1-FY03	SHORTHEAD REDHORSE	River	Y	< 0.099	< 0.099	< 0.099	ND			

* Lipid content not available; based on average for other shorthead redhorse samples.
** Total PCB equals the sum of detected concentrations for yealing samples.
Whole fish concentrations were calculated based on the relative wet weights of the tissues. The PCB concentrations in the fillet and in the carcass were multiplied by their individual wet weights, the two products were added and then divided by the total fish wet weight. Non-detects were included at one-half the detection limit.
For adult fish, whole body PCB concentration equals sum of fillet plus carcass sample
ND = Not detected.
All concentrations in mg/kg
Wet weight basis.

Table A-2
Average Lipid and Moisture Contents in Fish Tissue
Manistique Harbor and River Site
Manistique, Michigan

Species	% Lipid - C	% Lipid - F	Total Lipids	% Moisture
		Adult Fish		
Walleye	1	0.6	1.6	
Walleye	4.6	1.3	5.9	
Walleye	2.6	1.3	3.9	
Walleye	3.7	0.5	4.2	
Walleye	4	0.3	4.3	
Walleye	6.7	0.7	7.4	
Walleye	5.4	0.35	5.75	81.5
Walleye	5.9	0.4	6.3	
Walleye	–	1.5	–	
Walleye	–	–	–	79.3
Walleye	11.4	–	–	
Walleye	4.23	1.59	5.82	
Walleye	–	–	–	
Average	**4.95**	**0.85**	**5.02**	**80.4**
Smallmouth Bass		1.6		77
Smallmouth Bass	13.8	1.6	15.4	
Average	**13.8**	**1.6**	**15.4**	**77**
Predator average	**5.2**	**0.9**	**6.1**	**79.3**
White Sucker	3.8	1.9	5.7	
White Sucker	7.9	1	8.9	79.3
White Sucker	3.4	0.6	4	77.9
White Sucker	4.7	1	5.7	80.8
White Sucker	5.4	0.7	6.1	79.2
White Sucker	5.3	1	6.3	62.5
White Sucker	–	–	–	
White Sucker	–	–	–	
Average	**5.08**	**1.03**	**6.12**	**75.9**
Shorthead Redhorse	8.2	2	10.2	
Shorthead Redhorse	7.4	2.8	10.2	
Shorthead Redhorse	6.1	3.3	9.4	69.3
Shorthead Redhorse	–	2.7	–	77.6
Average	**7.23**	**2.70**	**9.93**	**73.5**
Longnose Sucker	–	–	–	77.7
Channel Catfish	9.6	4.7	14.3	74.9
Bottomfeeder average	**6.18**	**1.90**	**8.08**	**75.5**
		Yearling Fish		
Walleye		2.9		
Walleye		2.7		
Average		**2.8**		
Smallmouth Bass		3.1		
Rock Bass				71.7
Shorthead Redhorse				

F-fillet
C - carcass
Blank spaces indicate no data available.
Only samples with both fillet and carcass % lipids measured were included in averaging.
Lipids are wet weight percentages.

TABLE A-3
SEDIMENT DATA (Locations with Less than 4 ft water depth)
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

SedID	Depth (FT)	Area	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	TOC (%)	TOCQ
MH1-SD006	2.45	BZ	OUTER	42	UJ	85	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	85	U	0.13	J
MH1-SD009	2.75	AOI	RIVER	43	U	87	U	43	U	43	U	80		43	U	43	U	80		0.50	J
MH1-SD010	3.9	BZ	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.14	J
MH1-SD013	2.9	BZ	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.11	J
MH1-SD014	3	BZ	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.13	J
MH1-SD019	3.5	BZ	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.24	J
MH1-SD020	2.8	BZ	RIVER	41	U	83	U	41	U	41	U	41	U	23	J	41	U	23		0.41	J
MH1-SD023	3.4	BZ	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	1.00	U
MH1-SD034	3.9	BZ	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.10	J
MH1-SD037	2.9	BZ	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.15	J
MH1-SD037DP	2.9	BZ	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.12	J
MH1-SD046	1.9	BZ	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.16	J
MH1-SD060	3.5	BZ	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.11	J
MH1-SD061	3	BZ	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.13	J
MH1-SD064	3.9	BZ	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.12	J
MH1-SD067	3.53	BZ	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.11	J
MH1-SD068	3.5	BZ	OUTER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.12	J
MH1-SD092	3.9	BZ	INNER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.15	J
MH1-SD101	4	AOI	RIVER	53	U	110	U	53	U	53	U	340	J	53	U	53	U	340		1.57	J
MH1-SD104	3.09	AOI	RIVER	43	U	88	U	43	U	43	U	45		43	U	43	U	45		4.71	J
MH1-SD134	3.73	AOI	RIVER	170	U	350	U	170	U	170	U	2800	J	170	U	170	U	2800		14.3	J
MH1-SD135	0.8	AOI	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.21	J
MH1-SD135DP	0.8	AOI	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.15	J
MH1-SD136	3.89	AOI	RIVER	140	U	280	U	140	U	140	U	830	J	140	U	140	U	830		13.0	
MH1-SD137	3.95	AOI	RIVER	180	U	370	U	180	U	180	U	4100		180	U	180	U	4100		15.2	
MH1-SD138	1.55	AOI	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.35	J
MH1-SD139	1.3	AOI	OUTER	41	UJ	83	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	83	U	0.11	J
MH1-SD141	1.93	AOI	OUTER	43	UJ	87	UJ	43	UJ	43	UJ	43	UJ	43	UJ	43	UJ	87	U	0.44	J
MH1-SD143	2.05	AOI	OUTER	43	UJ	88	UJ	43	UJ	43	UJ	48	J	43	UJ	43	UJ	48		0.50	J
MH1-SD144	1.9	AOI	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.33	J
MH1-SD145	3.97	AOI	RIVER	120	U	250	U	120	U	120	U	1200		120	U	120	U	1200		11.8	J
MH1-SD146	3.93	AOI	RIVER	38	U	78	U	38	U	38	U	38	U	38	U	38	U	78	U	0.32	J
MH1-SD147	2.6	AOI	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.11	J
MH1-SD148	4.35	AOI	RIVER	130	U	270	U	130	U	130	U	130	U	130	U	130	U	270	U	11.7	
MH1-SD149	2.1	AOI	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.10	J
MH1-SD150	2.75	AOI	OUTER	43	UJ	88	UJ	43	UJ	43	UJ	31	J	43	UJ	43	UJ	31		0.22	J
MH1-SD151	2.65	AOI	OUTER	40	UJ	81	UJ	40	UJ	40	UJ	40	UJ	40	UJ	40	UJ	81	U	0.16	J
MH1-SD153	3.9	AOI	OUTER	42	U	86	U	42	U	42	U	42	U	170		42	U	170		0.12	J
MH1-SD154	3.01	AOI	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.16	J
MH1-SD155	2.73	AOI	OUTER	39	U	80	U	39	U	39	U	39	U	39	U	39	U	80	U	0.12	J
MH1-SD159	3.1	AOI	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	1.00	U
MH1-SD160	2.65	AOI	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.16	J
MH1-SD160DP	2.65	AOI	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.12	J
MH1-SD161	1.35	AOI	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.15	J
MH1-SD164	2.7	AOI	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.13	J
MH1-SD165	1.9	AOI	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.10	J
MH1-SD169	1.9	AOI	OUTER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.10	J
MH1-SD173	2	AOI	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	1.00	U
MH1-SD174	3.49	AOI	RIVER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.47	J
MH1-SD181	0.6	AOI	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.16	J
MH1-SD182	1.35	AOI	RIVER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	0.72	J
MH1-SD182DP	1.35	AOI	RIVER	45	U	92	U	45	U	45	U	88		45	U	45	U	88		0.62	J
MH1-SD347	2.9	AOI	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	1.00	U
MH1-SD361	3.89	AOI	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.12	J
MH1-SD362	3.45	AOI	OUTER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U		
MH1-SD376	3.42	AOI	OUTER	67	U	140	U	67	U	67	U	700	J	67	U	67	U	700		16.0	
MH1-SD388	2.82	AOI	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.24	J
MH1-SD388DP	2.82	AOI	OUTER	43	U	88	U	43	U	43	U	43	U	1200	J	43	U	1200		1.00	U
MH1-SD389	3.09	AOI	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.18	J
MH1-SD402	1.3	AOI	OUTER	41	U	84	U	41	U	41	U	15	J	41	U	41	U	15		0.17	J
MH1-SD415	2.52	AOI	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.11	J
MH1-SD531	3.85	AOI	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.12	J

TABLE A-3
SEDIMENT DATA (Locations with Less than 4 ft water depth)
MANISTIQUE HARBOR AND RIVER SITE
MANISTIQUE, MICHIGAN

All Concentrations in ug/kg

Sed1016	Aroclor 1016 concentration
Sed1016Q	Data qualifier for Aroclor 1016
Sed1221	Aroclor 1221 concentration
Sed1221Q	Data qualifier for Aroclor 1221
Sed1232	Aroclor 1232 concentration
Sed1232Q	Data qualifier for Aroclor 1232
Sed1242	Aroclor 1242 concentration
Sed1242L	Detection limit for Aroclor 1242
Sed1242Q	Data qualifier for Aroclor 1242
Depth	Water depth
Sed1248	Aroclor 1248 concentration
Sed1248I	Detection limit for Aroclor 1248
Sed1248(	Data qualifier for Aroclor 1248
Sed1254	Aroclor 1254 concentration
Sed1254(	Data qualifier for Aroclor 1254
Sed1260	Aroclor 1260 concentration
Sed1260(	Data qualifier for Aroclor 1260
SedPCB	Total PCBs
Area	Sample location in the AOI (area of interest) or BZ (background zone)
RIO	Sample location in river, inner harbor, or outer harbor
TOC	Total organic carbon
TOCQ	Data qualifier for TOC

Table A-4
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	R/O	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
MH1-SD001	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.24	J
MH1-SD002	RIVER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U	0.28	J
MH1-SD002DP	RIVER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.34	J
MH1-SD003	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.27	J
MH1-SD004	RIVER	44	U	89	U	44	U	44	U	110	J	44	U	44	U	110		0.53	J
MH1-SD005	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.22	J
MH1-SD006	OUTER	42	UJ	85	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	85	U	0.13	J
MH1-SD007	RIVER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.27	J
MH1-SD008	OUTER	110	U	220	U	110	U	110	U	1700		1700		240		3640		13.6	
MH1-SD008DP	OUTER	130	U	260	U	130	U	130	U	1600		860		130	U	2260		16.4	
MH1-SD009	RIVER	43	U	87	U	43	U	43	U	80		43	U	43	U	80		0.50	J
MH1-SD010	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.14	J
MH1-SD011	RIVER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.26	J
MH1-SD012	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.21	J
MH1-SD013	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.11	J
MH1-SD014	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.13	J
MH1-SD015	RIVER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.35	J
MH1-SD016	OUTER	45	U	91	U	45	U	45	U	210	J	45	U	45	U	210		0.82	J
MH1-SD016DP	OUTER	43	U	88	U	43	U	43	U	170	J	43	U	43	U	170		0.87	J
MH1-SD017	RIVER	52	U	110	U	52	U	52	U	52	U	52	U	52	U	52	U	1.51	J
MH1-SD018	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.12	J
MH1-SD019	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.24	J
MH1-SD020	RIVER	41	U	83	U	41	U	41	U	41	U	23	J	41	U	23		0.41	J
MH1-SD021	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.25	J
MH1-SD022	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.40	J
MH1-SD023	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	1.00	U
MH1-SD024	RIVER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.30	J
MH1-SD025	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.19	J
MH1-SD026	RIVER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.22	J
MH1-SD027	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.19	J
MH1-SD028	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.17	J
MH1-SD028DP	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.15	J
MH1-SD029	OUTER	47	U	96	U	47	U	47	U	47	U	47	U	47	U	96	U	0.84	J
MH1-SD030	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	1.00	U
MH1-SD031	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.33	J
MH1-SD032	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.14	J
MH1-SD033	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.25	J
MH1-SD034	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.10	J
MH1-SD035	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.23	J
MH1-SD036	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.18	J
MH1-SD037	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.15	J
MH1-SD037DP	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.12	J
MH1-SD039	RIVER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U	0.43	J
MH1-SD041	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.11	J
MH1-SD042	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.17	J
MH1-SD043	RIVER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.17	J
MH1-SD044	OUTER	170	U	340	U	170	U	170	U	490		240	J	170	U	730		13.0	
MH1-SD045	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.13	J
MH1-SD046	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.16	J
MH1-SD047	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.38	J
MH1-SD048	RIVER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.17	J
MH1-SD049	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.13	J
MH1-SD050	OUTER	69	U	140	U	69	U	69	U	69	U	69	U	69	U	69	U	1.46	J
MH1-SD051	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	1.00	U
MH1-SD052	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.12	J
MH1-SD052DP	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.11	J
MH1-SD053	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.11	J
MH1-SD054	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.46	J
MH1-SD055	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.12	J
MH1-SD056	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.16	J
MH1-SD057	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	1.00	U
MH1-SD057DP	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.19	J
MH1-SD058	RIVER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	0.32	J
MH1-SD059	RIVER	57	U	120	U	57	U	57	U	57	U	57	U	57	U	57	U	2.10	
MH1-SD060	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.11	J
MH1-SD061	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.13	J
MH1-SD062	RIVER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	1.00	U
MH1-SD063	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.31	J
MH1-SD064	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.12	J
MH1-SD065	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.14	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

BedID	RIO	Bed1016	Bed1016Q	Bed1221	Bed1221Q	Bed1232	Bed1232Q	Bed1242	Bed1242Q	Bed1248	Bed1248Q	Bed1254	Bed1254Q	Bed1260	Bed1260Q	BedPCB (ug/kg)	BedPCBQ	BedTOC (%)	BedTOCQ
[illegible]	RIVER	46	U	92	U	46	U	46	U	46	U	46	U	46	U	92	U	0.40	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.11	J
[illegible]	OUTER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.12	J
[illegible]	INNER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.66	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.14	J
[illegible]	INNER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.25	J
[illegible]	INNER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.14	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.13	J
[illegible]	INNER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.18	J
[illegible]	OUTER	61	U	130	U	61	U	61	U	61	U	67		61	U	67		2.16	
[illegible]	INNER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.16	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.34	J
[illegible]	INNER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.14	J
[illegible]DP	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.34	J
[illegible]	INNER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.16	J
[illegible]	INNER	46	U	91	U	46	U	46	U	46	U	46	U	46	U	91	U	0.12	J
[illegible]	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	1.00	U
[illegible]	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.21	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.19	J
[illegible]	INNER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.21	J
[illegible]	OUTER	43	U	86	U	43	U	43	U	440		210		43	U	660		0.66	J
[illegible]DP	OUTER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.80	J
[illegible]	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.10	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.82	J
[illegible]DP	INNER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.86	J
[illegible]	INNER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.14	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.27	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.30	J
[illegible]	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.16	J
[illegible]DP	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.37	J
[illegible]	INNER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.16	J
[illegible]	INNER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.22	J
[illegible]	OUTER	46	U	92	U	46	U	46	U	46	U	46	U	46	U	92	U	0.27	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.11	J
[illegible]	OUTER	51	U	100	U	51	U	51	U	51	U	51	U	51	U	51	U	0.42	J
[illegible]	OUTER	44	UJ	88	UJ	44	UJ	44	UJ	44	UJ	44	UJ	44	UJ	88	U	0.18	J
[illegible]	OUTER	54	U	110	U	54	U	54	U	3400		3300		400		7100		1.60	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.22	J
[illegible]	RIVER	53	U	110	U	53	U	53	U	340	J	53	U	53	U	340		1.67	J
[illegible]	RIVER	87	U	180	U	87	U	87	U	490	J	87	U	87	U	490		6.66	J
[illegible]DP	RIVER	80	U	190	U	80	U	80	U	770	J	300		40	J	1070		4.92	J
[illegible]	RIVER	110	U	220	U	110	U	110	U	1600	J	400	J	83	J	1983		7.41	J
[illegible]	RIVER	43	U	88	U	43	U	43	U	48		43	U	43	U	48		4.71	J
[illegible]	RIVER	83	U	170	U	83	U	83	U	4000		1700		390	J	6090		8.08	J
[illegible]	RIVER	79	U	160	U	79	U	79	U	6000		2800		270		8070		6.46	J
[illegible]	RIVER	88	U	120	U	88	U	88	U	1600	J	88	U	88		1688		2.66	J
[illegible]	RIVER	180	U	320	U	180	U	180	U	870	J	180	U	180	U	870		8.78	J
[illegible]	RIVER	42	U	87	U	43	U	42	U	8000		2400	J	170	J	10570		1.38	J
[illegible]	RIVER	83	U	170	U	83	U	83	U	2400		1200	J	220		4820		8.08	J
[illegible]	RIVER	91	U	190	U	91	U	91	U	480	J	91	U	91	U	430		2.17	J
[illegible]DP	RIVER	93	U	120	U	93	U	93	U	720	J	93	U	93	U	720		2.96	J
[illegible]	RIVER	180	U	360	U	180	U	180	U	700	J	180	U	180	U	700		6.94	J
[illegible]	RIVER	110	U	220	U	110	U	110	U	1600	J	110	U	99	J	1699		5.42	J
[illegible]	RIVER	140	U	280	U	140	U	140	U	880	J	140	U	140	U	880		9.01	J
[illegible]	RIVER	170	U	380	U	170	U	170	U	480	J	170	U	170	U	480		9.92	J
[illegible]DP	RIVER	180	U	370	U	180	U	180	U	680	J	180	U	180	U	680		9.04	J
[illegible]	RIVER	170	U	340	U	170	U	170	U	410	J	170	U	170	U	410		8.31	
[illegible]	RIVER	180	U	320	U	180	U	180	U	1700	J	180	U	180	U	1700		8.88	J
[illegible]	RIVER	72	U	190	U	72	U	72	U	10000		4000	J	290	J	19180		3.24	
[illegible]	RIVER	180	U	280	U	180	U	180	U	1000	J	180	U	180	U	1000		10.6	J
[illegible]	RIVER	42	U	88	U	42	U	42	U	83	J	42	U	42	U	83		0.44	J
[illegible]	RIVER	91	U	180	U	91	U	91	U	290	J	91	U	91	U	290		1.24	J

[illegible] [illegible]

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
MH1-SD127	RIVER	110	U	230	U	110	U	110	U	180	J	110	U	110	U	180		6.48	J
MH1-SD129	RIVER	49	U	100	U	49	U	49	U	49	U	49	U	49	U	49	U	1.23	J
MH1-SD130	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.22	J
MH1-SD131	RIVER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.30	J
MH1-SD132	RIVER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.36	J
MH1-SD133	RIVER	170	U	350	U	170	U	170	U	5700		1200		170	U	6900		13.9	J
MH1-SD134	RIVER	170	U	350	U	170	U	170	U	2800	J	170	U	170	U	2800		14.3	J
MH1-SD135	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.21	J
MH1-SD135DP	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.15	J
MH1-SD136	RIVER	140	U	280	U	140	U	140	U	830	J	140	U	140	U	830		13.0	
MH1-SD137	RIVER	180	U	370	U	180	U	180	U	4100		180	U	180	U	4100		15.2	
MH1-SD138	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.35	J
MH1-SD139	OUTER	41	UJ	83	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	83	U	0.11	J
MH1-SD140	RIVER	140	U	280	U	140	U	140	U	1900		140	U	140	U	1900		10.1	J
MH1-SD141	OUTER	43	UJ	87	UJ	43	UJ	43	UJ	43	UJ	43	UJ	43	UJ	87	U	0.44	J
MH1-SD142	RIVER	160	U	320	U	160	U	160	U	1400		160	U	160	U	1400		12.0	J
MH1-SD143	OUTER	43	UJ	88	UJ	43	UJ	43	UJ	48	J	43	UJ	43	UJ	48		0.50	J
MH1-SD144	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.33	J
MH1-SD145	RIVER	120	U	250	U	120	U	120	U	1200		120	U	120	U	1200		11.8	J
MH1-SD146	RIVER	38	U	78	U	38	U	38	U	38	U	38	U	38	U	78	U	0.32	J
MH1-SD147	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.11	J
MH1-SD148	RIVER	130	U	270	U	130	U	130	U	130	U	130	U	130	U	270	U	11.7	
MH1-SD149	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.10	J
MH1-SD150	OUTER	43	UJ	88	UJ	43	UJ	43	UJ	31	J	43	UJ	43	UJ	31		0.22	J
MH1-SD151	OUTER	40	UJ	81	UJ	40	UJ	40	UJ	40	UJ	40	UJ	40	UJ	81	U	0.16	J
MH1-SD152	RIVER	73	U	150	U	73	U	73	U	73	U	73	U	73	U	73	U	8.16	J
MH1-SD152DP	RIVER	77	U	160	U	77	U	77	U	330	J	130		77	U	460		7.03	J
MH1-SD153	OUTER	42	U	86	U	42	U	42	U	42	U	170		42	U	170		0.12	J
MH1-SD154	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.16	J
MH1-SD155	OUTER	39	U	80	U	39	U	39	U	39	U	39	U	39	U	80	U	0.12	J
MH1-SD156	RIVER	160	U	320	U	160	U	160	U	160	U	1300		160	U	1300		11.6	J
MH1-SD157	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.19	J
MH1-SD158	OUTER	54	U	110	U	54	U	54	U	410		150		54	U	560		3.29	
MH1-SD159	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	1.00	U
MH1-SD160	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	84	U	0.16	J
MH1-SD160DP	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.12	J
MH1-SD161	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.15	J
MH1-SD162	RIVER	100	U	200	U	100	U	100	U	1800		360		100	U	2160		10.3	J
MH1-SD163	OUTER	43	U	86	U	43	U	43	U	22	J	43	U	43	U	22		0.16	J
MH1-SD164	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.13	J
MH1-SD165	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.10	J
MH1-SD167	RIVER	38	U	78	U	38	U	38	U	38	U	38	U	38	U	78	U	0.35	J
MH1-SD168	OUTER	75	U	150	U	75	U	75	U	640		75	U	75	U	640		7.08	
MH1-SD169	OUTER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.10	J
MH1-SD170	RIVER	67	U	180	U	87	U	87	U	2000		420		87	U	2420		6.51	
MH1-SD171	RIVER	39	U	80	U	39	U	39	U	39	U	39	U	39	U	80	U	0.22	J
MH1-SD172	OUTER	79	U	160	U	79	U	79	U	4800		3300		200		8300		26.1	
MH1-SD173	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	1.00	U
MH1-SD174	RIVER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.47	J
MH1-SD175	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.17	J
MH1-SD176	OUTER	110	U	230	U	110	U	110	U	2000	J	1100		110	U	3100		29.3	
MH1-SD177	OUTER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U	0.23	J
MH1-SD178	RIVER	77	U	160	U	77	U	77	U	640		250		77	U	890		5.15	
MH1-SD179	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.13	J
MH1-SD179DP	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.15	J
MH1-SD180	OUTER	45	U	91	U	45	U	45	U	69	J	45	U	45	U	69		0.86	J
MH1-SD181	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.16	J
MH1-SD182	RIVER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	0.72	J
MH1-SD182DP	RIVER	45	U	92	U	45	U	45	U	88		45	U	45	U	88		0.62	J
MH1-SD183	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.17	J
MH1-SD184	OUTER	45	U	91	U	45	U	45	U	91		45	U	45	U	91		0.57	J
MH1-SD184DP	OUTER	43	U	87	U	43	U	43	U	460	J	43	U	43	U	460		0.35	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
[illegible]	OUTER	44	U	88	U	44	U	44	U	44	U	44	U	44	U	88	U	1.00	
[illegible]	RIVER	90	U	100	U	90	U	90	U	90	U	90	U	90	U	90	U	1.00	
[illegible]	RIVER	69	U	140	U	69	U	69	U	69	U	69	U	69	U	69	U	7.94	J
[illegible]	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.23	J
[illegible]	OUTER	49	U	88	U	49	U	49	U	210		74	J	49	U	284		2.04	
[illegible]	OUTER	44	U	88	U	44	U	44	U	44	U	44	U	44	U	88	U	0.26	J
[illegible]	RIVER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	1.20	
[illegible]	RIVER	43	U	86	U	43	U	43	U	43	U	43	U	43	U	86	U	0.22	J
[illegible]	OUTER	150	U	300	U	150	U	150	U	150	U	150	U	150	U	300	U	30.8	J
[illegible]	OUTER	43	U	88	U	43	U	43	U	49	J	28	J	43	U	74		0.21	J
[illegible]	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	86	U	0.17	J
[illegible]	RIVER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.82	J
[illegible]	OUTER	49	U	98	U	49	U	49	U	49	U	150		49	U	150		0.88	J
[illegible]	OUTER	160	U	280	U	160	U	160	U	24000		160	U	160	U	24000		21.3	
[illegible]	OUTER	120	U	260	U	130	U	130	U	980	J	400		130	U	1330		21.9	
[illegible]	OUTER	69	U	120	U	69	U	69	U	400	J	160	J	69	U	560		1.67	
[illegible]	OUTER	43	U	86	U	43	U	43	U	43	U	43	U	43	U	86	U	0.19	J
[illegible]	OUTER	86	U	170	U	86	U	86	U	790	J	86	U	86	U	790		6.66	
[illegible]	OUTER	45	U	87	U	45	U	43	U	300		130		45	U	430		0.64	J
[illegible]	OUTER	49	U	100	U	49	U	49	U	1900	J	1900	J	380	J	4080		5.13	
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.28	J
[illegible]	RIVER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.17	J
[illegible]	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	38.4	
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.14	J
[illegible]DP	OUTER	41	U	84	U	41	U	41	U	38	J	19	J	41	U	84		0.22	J
[illegible]	OUTER	220	U	450	U	220	U	220	U	2300	J	1300	J	220	U	4800		0.28	J
[illegible]0210	OUTER	44	U	88	U	44	U	44	U	640	J	130	J	44	U	770		0.86	J
[illegible]0211	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.17	J
[illegible]0212	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.20	J
[illegible]0214	OUTER	46	U	94	U	46	U	46	U	46	U	6000		46	U	6600		0.79	J
[illegible]0215	OUTER	83	U	170	U	83	U	83	U	7700		83	U	83	U	7700		0.36	J
[illegible]DP	OUTER	42	U	86	U	42	U	42	U	83	J	42	U	42	U	83		0.40	J
[illegible]	OUTER	46	U	93	U	46	U	46	U	46	U	830	J	46	U	830		0.43	J
[illegible]	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.17	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.27	J
[illegible]	OUTER	56	U	110	U	56	U	56	U	480	J	56	U	56	U	480		3.04	
[illegible]	OUTER	42	U	86	U	42	U	42	U	330	J	42	U	42	U	330		0.36	J
[illegible]DP	OUTER	42	U	86	U	42	U	42	U	86		42	U	42	U	86		0.80	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.31	J
[illegible]	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.13	J
[illegible]	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.29	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.18	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.14	J
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	1.27	
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.17	J
[illegible]	OUTER	42	U	88	U	42	U	42	U	42	U	42	U	42	U	86	U	0.10	J
[illegible]	OUTER	43	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	1.00	U
[illegible]	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	1.00	U
[illegible]	OUTER	50	U	100	U	50	U	50	U	50	U	50	U	50	U	50	U	1.17	
[illegible]	OUTER	100	U	200	U	100	U	100	U	100	U	100	U	100	U	200	U	7.48	J
[illegible]	OUTER	66	U	120	U	66	U	66	U	66	U	66	U	66	U	66	U	2.16	
[illegible]	OUTER	67	U	130	U	67	U	67	U	67	U	67	U	67	U	67	U	2.86	J
[illegible]	OUTER	190	U	380	U	190	U	190	U	190	U	190	U	190	U	380	U	20.6	
[illegible]	OUTER	46	U	92	U	46	U	46	U	46	U	46	U	46	U	92	U	0.66	J
[illegible]	OUTER	120	U	250	U	120	U	120	U	120	U	120	U	120	U	250	U	11.6	
[illegible]	OUTER	210	U	420	U	210	U	210	U	210	U	210	U	210	U	420	U	27.1	
[illegible]	OUTER	49	U	99	U	49	U	49	U	49	U	49	U	49	U	99	U	0.62	J
[illegible]	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	1.04	
[illegible]DP	OUTER	54	U	110	U	54	U	54	U	68	J	37	J	54	U	68		1.40	
[illegible]	OUTER	100	U	210	U	100	U	100	U	11000		100	U	480		11480		6.32	J
[illegible]	OUTER	200	U	610	U	200	U	200	U	200	U	200	U	200	U	610	U	20.0	J
[illegible]	OUTER	140	U	280	U	140	U	140	U	140	U	220		140	U	220		13.2	

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
MH1-SD244	OUTER	59	U	120	U	59	U	59	U	490	J	170	J	59	U	660		1.48	
MH1-SD245	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.70	J
MH1-SD246	OUTER	47	U	96	U	47	U	47	U	47	U	47	U	47	U	96	U	0.70	J
MH1-SD247	OUTER	45	UJ	92	UJ	45	UJ	45	UJ	45	UJ	45	UJ	45	UJ	92	U	0.38	J
MH1-SD248	OUTER	89	U	180	U	89	U	89	U	89	U	89	U	89	U	89	U	7.08	J
MH1-SD249	OUTER	170	U	340	U	170	U	170	U	170	U	170	U	170	U	340	U	11.2	
MH1-SD249DP	OUTER	190	U	390	U	190	U	190	U	190	U	190	U	190	U	390	U	11.5	
MH1-SD250	OUTER	94	U	190	U	94	U	94	U	94	U	94	U	94	U	94	U	6.39	
MH1-SD251	OUTER	65	U	130	U	65	U	65	U	65	U	65	U	65	U	65	U	1.55	
MH1-SD251DP	OUTER	62	U	130	U	62	U	62	U	62	U	62	U	62	U	62	U	2.28	
MH1-SD252	OUTER	56	U	110	U	56	U	56	U	740	J	210	J	56	U	950		0.96	J
MH1-SD253	OUTER	46	UJ	93	UJ	46	UJ	46	UJ	46	UJ	46	UJ	46	UJ	93	U	0.54	J
MH1-SD254	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	86	U	0.24	J
MH1-SD255	OUTER	51	U	100	U	51	U	51	U	51	U	51	U	51	U	51	U	1.31	J
MH1-SD256	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.76	J
MH1-SD257	OUTER	220	U	450	U	220	U	220	U	220	U	220	U	220	U	450	U	16.6	J
MH1-SD257DP	OUTER	170	U	340	U	170	U	170	U	170	U	170	U	170	U	340	U	13.8	J
MH1-SD258	OUTER	75	U	150	U	75	U	75	U	75	U	75	U	75	U	75	U	3.73	
MH1-SD259	OUTER	45	U	91	U	45	U	45	U	32	J	45	U	45	U	32		1.37	
MH1-SD260	OUTER	60	U	120	U	60	U	60	U	60	U	60	U	60	U	60	U	1.51	
MH1-SD261	OUTER	45	U	92	U	45	U	45	U	65		45	U	45	U	65		3.77	
MH1-SD262	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.35	J
MH1-SD263	OUTER	170	U	340	U	170	U	170	U	170	U	170	U	170	U	340	U	9.36	J
MH1-SD264	OUTER	80	U	160	U	80	U	80	U	80	U	80	U	80	U	80	U	7.34	J
MH1-SD265	OUTER	280	U	560	U	280	U	280	U	35000		280	U	1200		36200		7.53	
MH1-SD266	OUTER	110	U	230	U	110	U	110	U	110	U	9700		110	U	9700		10.2	
MH1-SD267	OUTER	75	U	150	U	75	U	75	U	350		75	U	75	U	350		4.92	
MH1-SD268	OUTER	65	U	130	U	65	U	65	U	110	J	65	U	65	U	110		3.24	
MH1-SD269	OUTER	62	U	130	U	62	U	62	U	78	J	62	U	62	U	78		2.05	
MH1-SD270	OUTER	52	U	110	U	52	U	52	U	83		52	U	52	U	83		2.38	
MH1-SD273	OUTER	57	U	120	U	57	U	57	U	57	U	57	U	57	U	57	U	1.68	J
MH1-SD274	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	3.08	J
MH1-SD275	OUTER	170	U	340	U	170	U	170	U	170	U	170	U	170	U	340	U	14.6	
MH1-SD276	OUTER	130	U	270	U	130	U	130	U	130	U	130	U	130	U	270	U	8.33	
MH1-SD277	OUTER	77	U	160	U	77	U	77	U	540	J	77	U	77	U	540		3.73	
MH1-SD278	OUTER	61	U	120	U	61	U	61	U	98	J	61	U	61	U	98		2.08	
MH1-SD278DP	OUTER	66	U	130	U	66	U	66	U	130	J	66	U	66	U	130		2.58	
MH1-SD279	OUTER	55	UJ	110	UJ	55	UJ	55	UJ	55	UJ	55	UJ	55	UJ	55	U	1.82	
MH1-SD280	OUTER	59	U	120	U	59	U	59	U	94	J	59	U	59	U	94		3.54	
MH1-SD281	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.43	J
MH1-SD282	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.19	J
MH1-SD283	OUTER	43	UJ	87	UJ	43	UJ	43	UJ	43	UJ	24	J	43	UJ	24		0.78	J
MH1-SD284	OUTER	120	U	240	U	120	U	120	U	180		120	U	120	U	180		4.65	J
MH1-SD284DP	OUTER	110	U	230	U	110	U	110	U	450		110	U	110	U	450		4.03	J
MH1-SD285	OUTER	57	U	120	U	57	U	57	U	57	U	890		150		1040		1.38	
MH1-SD285DP	OUTER	51	U	100	U	51	U	51	U	51	U	51	U	51	U	51	U	1.14	
MH1-SD286	OUTER	130	U	260	U	130	U	130	U	130	U	130	U	130	U	260	U	10.5	J
MH1-SD287	OUTER	80	U	160	U	80	U	80	U	80	U	290		80	U	290		7.97	
MH1-SD288	OUTER	67	U	140	U	67	U	67	U	85		67	U	67	U	85		4.19	
MH1-SD289	OUTER	92	U	190	U	92	U	92	U	420		92	U	92	U	420		5.53	
MH1-SD290	OUTER	66	UJ	130	UJ	66	UJ	66	UJ	66	UJ	66	UJ	66	UJ	66	U	2.77	
MH1-SD291	OUTER	59	UJ	120	UJ	59	UJ	59	UJ	500	J	59	UJ	59	UJ	500		1.34	
MH1-SD292	OUTER	52	U	110	U	52	U	52	U	240	J	52	U	52	U	240		2.62	
MH1-SD293	OUTER	45	UJ	92	UJ	45	UJ	45	UJ	45	UJ	45	UJ	45	UJ	92	U	0.45	J
MH1-SD295	OUTER	54	UJ	110	UJ	54	UJ	54	UJ	54	UJ	240	J	54	UJ	240		2.55	
MH1-SD296	OUTER	89	U	180	U	89	U	89	U	95	J	89	U	89	U	95		3.25	J
MH1-SD297	OUTER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	1.09	J
MH1-SD298	OUTER	54	U	110	U	54	U	54	U	54	U	54	U	54	U	54	U	1.73	
MH1-SD299	OUTER	110	U	220	U	110	U	110	U	110	U	110	U	110	U	220	U	13.3	
MH1-SD300	OUTER	75	U	150	U	75	U	75	U	75	U	70	J	75	U	70		8.52	
MH1-SD301	OUTER	72	U	150	U	72	U	72	U	140	J	72	U	72	U	140		3.27	
MH1-SD302	OUTER	94	U	190	U	94	U	94	U	94	U	94	U	94	U	94	U	6.81	

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
[illegible]	OUTER	79	U	180	U	79	U	79	U	79	U	820	J	79	U	820		9.40	
[illegible]	OUTER	70	U	140	U	70	U	70	U	70	U	70	J	70	U	70	U	6.60	
[illegible]	OUTER	83	UJ	110	UJ	83	UJ	83	UJ	740	J	83	UJ	83	UJ	740		2.01	
[illegible]	OUTER	44	UJ	88	UJ	44	UJ	44	UJ	81	J	44	UJ	44	UJ	81		0.71	J
[illegible]DP	OUTER	46	UJ	91	UJ	46	UJ	46	UJ	46	UJ	46	UJ	46	UJ	91	U	0.19	J
[illegible]	OUTER	[illegible]	U	[illegible]	U	44	U	44	U	44		44	U	44	U	44		[illegible]	J
[illegible]	OUTER	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	J	[illegible]	J	[illegible]	UJ	[illegible]		[illegible]	
[illegible]DP	OUTER	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	J	110	J	[illegible]	UJ	470		[illegible]	
[illegible]	OUTER	[illegible]	U	[illegible]	U	42	U	42	U	41	U	42	U	43	U	[illegible]	U	0.19	J
[illegible]	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	
[illegible]	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]		[illegible]	U	[illegible]	U	[illegible]		2.07	J
[illegible]	OUTER	170	U	[illegible]	U	170	U	170	U	170	U	[illegible]		170	U	[illegible]		[illegible]	
[illegible]	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	J	110		[illegible]	U	[illegible]		[illegible]	
[illegible]	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	1400		[illegible]	U	1400		1.01	
[illegible]DP	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	J	120	J	[illegible]	U	[illegible]		[illegible]	
[illegible]	OUTER	[illegible]	U	[illegible]	U	[illegible]	U	[illegible]	U	310	J	[illegible]	U	[illegible]	U	310		[illegible]	
[illegible]	OUTER	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	UJ	[illegible]	J	[illegible]	UJ	[illegible]	UJ	[illegible]		[illegible]	
[illegible]	OUTER	[illegible]	U	110	U	[illegible]	U	[illegible]	U	1700	J	[illegible]	U	[illegible]	U	1700		[illegible]	
[illegible]DP	OUTER	[illegible]	U	140	U	[illegible]	U	[illegible]	U	4000	J	[illegible]	U	[illegible]	U	4000		[illegible]	
[illegible]	OUTER	46	UJ	92	UJ	46	UJ	46	UJ	58	J	46	UJ	46	UJ	58		0.43	J
[illegible]	OUTER	40	UJ	83	UJ	40	UJ	40	UJ	40	UJ	40	UJ	40	UJ	83	U	0.21	J
[illegible]	OUTER	44	U	88	U	44	U	44	U	44	U	44	U	44	U	88	U	1.66	J
[illegible]	OUTER	46	U	92	U	46	U	46	U	46	U	46	U	46	U	92	U	1.63	
[illegible]	OUTER	63	U	110	U	63	U	63	U	63	U	63	U	63	U	63	U	2.37	
[illegible]	OUTER	64	U	180	U	64	U	64	U	64	U	64	U	64	U	64	U	1.47	
[illegible]DP	OUTER	100	U	200	U	100	U	100	U	100	U	100	U	100	U	200	U	0.88	
[illegible]	OUTER	63	U	130	U	63	U	63	U	310		63	U	63	U	310		0.62	J
[illegible]	OUTER	67	UJ	140	U	67	UJ	67	U	87	UJ	67	UJ	67	U	67	U	4.61	
[illegible]	OUTER	66	U	130	U	66	U	66	U	310	J	66	U	66	U	310		2.74	
[illegible]	OUTER	82	U	130	U	82	U	82	U	810	J	82	U	1100	J	1910		2.93	
[illegible]	OUTER	58	UJ	120	UJ	58	UJ	58	UJ	300	J	100	J	58	UJ	400		4.14	
[illegible]	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.77	J
[illegible]	OUTER	42	U	88	U	42	U	42	U	41	J	42	U	43	U	41		0.88	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.76	J
[illegible]	OUTER	45	U	91	U	46	U	46	U	62		47	U	46	U	62		0.30	J
[illegible]	OUTER	54	U	110	U	54	U	54	U	54	U	54	U	54	U	54	U	0.63	J
[illegible]	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	1.77	
[illegible]	OUTER	57	U	120	U	57	U	57	U	57	U	57	U	57	U	57	U	1.95	J
[illegible]	OUTER	60	U	120	U	60	U	60	U	60	U	60	U	60	U	60	U	1.40	
[illegible]	OUTER	82	U	190	U	82	U	82	U	84	J	82	U	82	U	84		0.87	
[illegible]	OUTER	48	U	97	U	48	U	48	U	48	U	200	J	48	U	200		0.79	J
[illegible]	OUTER	64	U	130	U	64	U	64	U	64	U	64	U	64	U	64	U	0.86	
[illegible]	OUTER	70	U	140	U	70	U	70	U	70	U	70	U	70	U	70	U	1.75	
[illegible]	OUTER	81	U	160	U	81	U	81	U	1000	J	81	U	81	U	1000		2.88	
[illegible]	OUTER	47	UJ	94	UJ	47	UJ	47	UJ	1200	J	47	UJ	24	J	1224		0.86	J
[illegible]	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.71	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	86		43	U	43	U	86		0.16	J
[illegible]	OUTER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	1.00	UJ
[illegible]	OUTER	41	UJ	84	UJ	41	UJ	41	UJ	120	J	41	UJ	41	UJ	120		0.79	J
[illegible]	OUTER	48	UJ	97	UJ	48	UJ	48	UJ	48	UJ	48	UJ	48	UJ	97	U	0.48	J
[illegible]	OUTER	52	U	110	U	52	U	52	U	52	U	53	U	52	U	52	U	0.79	J
[illegible]	OUTER	61	U	120	U	61	U	61	U	61	U	61	U	61	U	61	U	1.71	J
[illegible]	OUTER	60	U	120	U	60	U	60	U	4600	J	120	UJ	60	U	4600		2.10	
[illegible]DP	OUTER	55	U	110	U	55	U	55	U	55	U	55	U	55	U	55	U	1.80	
[illegible]	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	0.72	J
[illegible]	OUTER	75	U	150	U	75	U	75	U	150	J	75	U	75	U	150		14.9	
[illegible]	OUTER	67	UJ	130	UJ	67	UJ	67	UJ	200	J	67	UJ	67	UJ	200		1.80	
[illegible]DP	OUTER	80	UJ	190	UJ	80	UJ	80	UJ	480	J	80	UJ	80	UJ	480		1.46	
[illegible]	OUTER	83	U	170	U	83	U	83	U	170	J	83	U	83	U	170		3.87	
[illegible]	OUTER	70	U	150	U	70	U	70	U	880	J	70	U	70	U	880		4.04	
[illegible]	OUTER	120	UJ	220	UJ	120	UJ	120	UJ	61	J	130	UJ	120	UJ	61		4.41	
[illegible]	OUTER	40	U	81	U	40	U	40	U	40	U	40	U	40	U	81	U	0.19	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
MH1-SD360	OUTER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	1.24	
MH1-SD360DP	OUTER	46	U	93	U	46	U	46	U	130		58		46	U	188		3.69	
MH1-SD361	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.12	J
MH1-SD362	OUTER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U		
MH1-SD366	OUTER	54	U	110	U	54	U	54	U	54	U	54	U	54	U	54	U	1.50	
MH1-SD367	OUTER	57	U	120	U	57	U	57	U	57	U	57	U	57	U	57	U	3.43	
MH1-SD368	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	1.24	
MH1-SD369	OUTER	47	UJ	96	UJ	47	UJ	47	UJ	47	UJ	47	UJ	47	UJ	96	U	0.95	J
MH1-SD370	OUTER	49	U	100	U	49	U	49	U	49	U	49	U	49	U	49	U	0.79	J
MH1-SD371	OUTER	62	U	130	U	62	U	62	U	62	U	1600	J	62	U	1600		3.75	
MH1-SD372	OUTER	60	U	120	U	60	U	60	U	780	J	60	U	60	U	780		7.10	
MH1-SD374	OUTER	51	U	100	U	51	U	51	U	1500		51	U	52		1552		3.15	
MH1-SD375	OUTER	45	U	91	U	45	U	45	U	45	U	280		45	U	280		0.36	J
MH1-SD376	OUTER	67	U	140	U	67	U	67	U	700	J	67	U	67	U	700		16.0	
MH1-SD377	OUTER	40	U	81	U	40	U	40	U	31	J	40	U	40	U	31		0.17	J
MH1-SD379	OUTER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.60	J
MH1-SD380	OUTER	50	U	100	U	50	U	50	U	50	U	50	U	50	U	50	U	1.45	
MH1-SD381	OUTER	73	U	150	U	73	U	73	U	73	U	420		73	U	420		4.21	
MH1-SD382	OUTER	62	UJ	130	UJ	62	UJ	62	UJ	62	UJ	62	UJ	62	UJ	62	U	2.13	
MH1-SD383	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	1.22	
MH1-SD384	OUTER	56	U	110	U	56	U	56	U	56	U	56	U	56	U	56	U	7.05	
MH1-SD385	OUTER	72	UJ	150	UJ	72	UJ	72	UJ	800	J	260	J	72	UJ	1060		4.65	
MH1-SD387	OUTER	70	U	140	U	70	U	70	U	750	J	240	J	70	U	990		4.55	
MH1-SD388	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.24	J
MH1-SD388DP	OUTER	43	U	88	U	43	U	43	U	43	U	1200	J	43	U	1200		1.00	U
MH1-SD389	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.18	J
MH1-SD390	OUTER	44	UJ	89	UJ	44	UJ	44	UJ	210	JJ	44	UJ	44	UJ	210			
MH1-SD391	OUTER	79	U	160	U	79	U	79	U	9300	J	3600		380	J	13250		6.85	J
MH1-SD392	OUTER	47	U	96	U	47	U	47	U	47	U	47	U	47	U	96	U	1.99	
MH1-SD393	OUTER	57	U	120	U	57	U	57	U	180		57	U	57	U	180		1.51	
MH1-SD394	OUTER	52	U	100	U	52	U	52	U	52	U	52	U	52	U	52	U	1.13	
MH1-SD395	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.71	J
MH1-SD396	OUTER	60	U	120	U	60	U	60	U	60	U	60	U	60	U	60	U	1.30	
MH1-SD396DP	OUTER	55	U	110	U	55	U	55	U	55	U	55	U	55	U	55	U	1.45	
MH1-SD397	OUTER	100	UJ	200	UJ	100	UJ	100	UJ	100	UJ	100	UJ	100	UJ	200	U	7.76	
MH1-SD398	OUTER	130	U	260	U	130	U	130	U	54000	J	130	U	130	U	54000		2.31	
MH1-SD399	OUTER	46	UJ	93	UJ	46	UJ	46	UJ	46	UJ	46	UJ	46	UJ	93	U	1.44	
MH1-SD400	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.28	J
MH1-SD401	OUTER	55	U	110	U	56	U	55	U	55	U	55	U	55	U	56	U	0.75	J
MH1-SD402	OUTER	41	U	84	U	41	U	41	U	15	J	41	U	41	U	15		0.17	J
MH1-SD403	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.40	J
MH1-SD404	OUTER	44	U	89	U	44	U	44	U	210	J	130		33	U	340		1.07	
MH1-SD405	OUTER	50	U	100	U	50	U	50	U	280	J	50	U	50	U	280		1.61	
MH1-SD406	OUTER	60	U	120	U	60	U	60	U	60	U	60	U	60	U	60	U	1.47	
MH1-SD407	OUTER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.28	J
MH1-SD408	OUTER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	0.63	J
MH1-SD409	OUTER	54	U	110	U	54	U	54	U	54	U	54	U	54	U	54	U	0.71	J
MH1-SD410	OUTER	55	UJ	110	UJ	55	UJ	55	UJ	55	UJ	55	UJ	55	UJ	55	U	1.18	
MH1-SD411	OUTER	55	UJ	110	UJ	55	UJ	55	UJ	30	J	55	UJ	55	UJ	30		1.40	
MH1-SD412	OUTER	61	UJ	120	UJ	61	UJ	61	UJ	76	J	61	UJ	61	UJ	76		1.60	
MH1-SD413	OUTER	43	UJ	87	UJ	43	UJ	43	UJ	43	UJ	43	UJ	43	UJ	87	U	0.34	J
MH1-SD415	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.11	J
MH1-SD416	OUTER	43	UJ	88	UJ	43	UJ	43	UJ	380	J	43	UJ	43	UJ	380		0.64	J
MH1-SD418	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.19	J
MH1-SD419	OUTER	52	U	110	U	52	U	52	U	52	U	52	U	52	U	52	U	2.03	
MH1-SD420	OUTER	45	U	91	U	45	U	45	U	45	U	45	U	45	U	91	U	0.27	J
MH1-SD421	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.34	J
MH1-SD422	OUTER	44	UJ	89	UJ	44	UJ	44	UJ	44	UJ	44	UJ	44	UJ	89		0.30	J
MH1-SD423	OUTER	44	UJ	89	UJ	44	UJ	44	UJ	3000	J	44	UJ	44	UJ	3000		0.65	J
MH1-SD424	OUTER	53	U	110	U	53	U	53	U	53	U	53	U	53	U	53	U	0.78	J
MH1-SD424DP	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.87	J
MH1-SD425	OUTER	49	UJ	99	UJ	49	UJ	49	UJ	49	UJ	49	UJ	49	UJ	99	U	0.60	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RID	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
[illegible]	OUTER	42	UJ	87	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	87	U	0.48	J
[illegible]	OUTER	80	U	160	U	80	U	80	U	80	U	80	U	80	U	80	U	4.28	
[illegible]	OUTER	48	U	97	U	48	U	48	U	80		72	J	48	U	102		0.83	J
[illegible]	OUTER	63	U	130	U	63	U	63	U	63	U	63	U	63	U	63	U	2.81	
[illegible]	OUTER	43	U	86	U	43	U	43	U	43	U	43	U	43	U	86	U	0.97	J
[illegible]	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.17	J
[illegible]	OUTER	38	UJ	78	UJ	38	UJ	38	UJ	38	UJ	38	UJ	38	UJ	78	U	0.14	J
[illegible]	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.38	J
[illegible]DP	OUTER	45	U	87	U	45	U	45	U	45	U	45	U	45	U	87	U	0.20	J
[illegible]	OUTER	46	U	91	U	46	U	46	U	46	U	46	U	46	U	91	U	0.33	J
[illegible]	OUTER	49	UJ	91	UJ	49	UJ	49	UJ	49	UJ	49	UJ	49	UJ	91	U	0.82	J
[illegible]	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.38	J
[illegible]DP	OUTER	46	UJ	91	UJ	46	UJ	46	UJ	46	UJ	46	UJ	46	UJ	91	U	0.37	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.30	J
[illegible]	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.18	J
[illegible]	OUTER	50	U	100	U	50	U	50	U	58	J	60	U	60	U	58		0.47	
[illegible]	OUTER	48	U	97	U	48	U	48	U	720		720	J	48	U	980		1.48	
[illegible]	OUTER	44	U	88	U	44	U	44	U	44	U	44	U	44	U	88	U	0.40	J
[illegible]	OUTER	48	U	100	U	48	U	48	U	48	U	48	U	48	U	49	U	0.81	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.89	J
[illegible]	OUTER	46	U	92	U	46	U	46	U	46	U	46	U	46	U	92	U	0.43	J
[illegible]	OUTER	44	UJ	89	UJ	44	UJ	44	UJ	44	UJ	44	UJ	44	UJ	89	U	0.14	J
[illegible]	OUTER	41	UJ	83	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	83	U	0.11	J
[illegible]	OUTER	40	UJ	82	UJ	40	UJ	40	UJ	40	UJ	40	UJ	40	UJ	82	U	0.14	J
[illegible]	OUTER	56	UJ	110	UJ	56	UJ	56	UJ	56	UJ	56	UJ	56	UJ	56	U	0.68	J
[illegible]	OUTER	40	U	80	U	40	U	40	U	630	J	40	U	40	U	630		1.28	J
[illegible]	OUTER	45	U	91	U	46	U	46	U	180	J	110	J	46	U	280		0.36	J
[illegible]	OUTER	60	U	120	U	60	U	60	U	120	J	60	U	60	U	120		2.88	
[illegible]	OUTER	41	UJ	83	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	83	U	0.25	J
[illegible]	OUTER	41	UJ	83	UJ	41	UJ	41	UJ	41	UJ	41	UJ	41	UJ	83	U	0.16	J
[illegible]	OUTER	51	U	100	U	51	U	51	U	380	J	51	U	51	U	380		3.02	
[illegible]	OUTER	40	U	100	U	40	U	40	U	82		34	J	40	U	86		1.28	
[illegible]	OUTER	67	U	120	U	67	U	67	U	87	U	180		67	U	180		0.84	J
[illegible]DP	OUTER	81	U	100	U	81	U	81	U	81	U	81	U	81	U	81	U	1.10	J
[illegible]	OUTER	43	U	87	U	43	U	43	U	800	J	380	J	43	U	1100		0.83	J
[illegible]	OUTER	77	U	180	U	77	U	77	U	77	U	77	U	77	U	77	U	4.74	
[illegible]	OUTER	83	U	110	U	83	U	83	U	83	U	83	U	83	U	83	U	2.11	J
[illegible]	OUTER	42	UJ	86	UJ	42	UJ	42	UJ	42	UJ	42	UJ	42	UJ	86	U	0.18	J
[illegible]	OUTER	48	U	97	U	48	U	48	U	88		48	U	48	U	88		1.20	
[illegible]DP	OUTER	47	U	88	U	47	U	47	U	47	U	480		47	U	480		1.71	
[illegible]	OUTER	82	U	100	U	82	U	82	U	82	U	82	U	82	U	82	U	0.72	J
[illegible]DP	OUTER	48	U	94	U	48	U	48	U	48	U	48	U	48	U	94	U	0.87	J
[illegible]	OUTER	48	U	98	U	48	U	48	U	48	U	48	U	48	U	98	U	0.80	J
[illegible]	OUTER	48	U	97	U	48	U	48	U	48	U	48	U	48	U	97	U	2.02	
[illegible]	OUTER	120	U	280	U	120	U	120	U	120	U	120	U	120	U	280	U	8.30	
[illegible]	OUTER	48	U	94	U	48	U	48	U	48	U	48	U	48	U	94	U	0.77	J
[illegible]	OUTER	48	U	98	U	48	U	48	U	81		34	J	48	U	115		0.92	J
[illegible]DP	OUTER	48	U	94	U	48	U	48	U	48	U	48	U	48	U	94	U	0.47	J
[illegible]	OUTER	48	U	91	U	48	U	48	U	330	J	140	J	48	U	470		1.09	
[illegible]DP	OUTER	48	U	93	U	48	U	48	U	180		48	U	48	U	180		0.90	J
[illegible]	OUTER	48	U	97	U	48	U	48	U	180	J	180		48	U	470		0.95	J
[illegible]	OUTER	48	U	94	U	48	U	48	U	48	U	48	U	48	U	94	U	0.93	J
[illegible]DP	OUTER	81	U	100	U	81	U	81	U	81	U	81	U	81	U	81	U	0.89	J
[illegible]	OUTER	82	U	100	U	82	U	82	U	82	U	82	U	82	U	82	U	1.92	
[illegible]	OUTER	44	U	88	U	44	U	44	U	44	U	44	U	44	U	88	U	1.09	J
[illegible]	OUTER	44	U	88	U	44	U	44	U	81	J	44	U	44	U	81		0.88	J
[illegible]	OUTER	90	U	120	U	90	U	90	U	90	U	90	U	90	U	90	U	1.82	
[illegible]	OUTER	98	U	110	U	98	U	98	U	140	J	98	U	98	U	140		0.79	J
[illegible]	OUTER	48	U	94	U	48	U	48	U	120		48	U	48	U	120		0.94	J
[illegible]DP	OUTER	48	U	94	U	48	U	48	U	48	U	48	U	48	U	94	U	0.89	J
[illegible]	OUTER	179	U	240	U	179	U	179	U	280		179	U	179	U	280		24.7	J
[illegible]	OUTER	82	U	110	U	82	U	82	U	82	U	82	U	82	U	82	U	1.37	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

SedID	RIO	Sed1016	Sed1016Q	Sed1221	Sed1221Q	Sed1232	Sed1232Q	Sed1242	Sed1242Q	Sed1248	Sed1248Q	Sed1254	Sed1254Q	Sed1260	Sed1260Q	SedPCB (ug/kg)	SedPCBQ	SedTOC (%)	SedTOCQ
MH1-SD482	OUTER	59	U	120	U	59	U	59	U	290		290		59	U	580		2.99	
MH1-SD483	OUTER	54	U	110	U	54	U	54	U	530	J	230		54	U	760		1.94	
MH1-SD485	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.26	J
MH1-SD486	OUTER	62	U	130	U	62	U	62.	U	62	U	62	U	62	U	62	U	2.40	J
MH1-SD487	OUTER	57	U	120	U	57	U	57	U	130	J	70		57	U	200		1.77	
MH1-SD488	OUTER	79	U	160	U	79	U	79	U	550		180	J	79	U	730		4.02	
MH1-SD489	OUTER	49	U	100	U	49	U	49	U	49	U	49	U	49	U	49	U	1.42	
MH1-SD490	OUTER	43	U	88	U	43	U	43	U	43	U	43	U	43	U	88	U	0.55	J
MH1-SD491	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.25	J
MH1-SD492	OUTER	67	U	140	U	67	U	67	U	970	J	670		67	U	1640		2.06	
MH1-SD493	OUTER	70	U	140	U	70	U	70	U	70	U	17000		70	U	17000		4.68	
MH1-SD494	OUTER	80	U	120	U	80	U	60	U	80	U	60	U	60	U	60	U	1.00	
MH1-SD495	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.45	J
MH1-SD496	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.44	J
MH1-SD497	OUTER	56	U	110	U	56	U	56	U	220		130		56	U	350		2.41	
MH1-SD498	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.19	J
MH1-SD498DP	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.14	J
MH1-SD499	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	1.00	U
MH1-SD500	OUTER	45	U	92	U	45	U	45	U	37	J	45	U	45	U	37		0.79	J
MH1-SD501	OUTER	70	U	140	U	70	U	70	U	460	J	190	J	70	U	650		3.74	
MH1-SD502	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.13	J
MH1-SD502DP	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.11	J
MH1-SD503	INNER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.16	J
MH1-SD504	OUTER	83	U	170	U	83	U	83	U	660		950	J	1400	J	3010		5.46	
MH1-SD505	OUTER	120	U	240	U	120	U	120	U	630	J	210	J	120	U	840		11.0	
MH1-SD506	OUTER	39	U	80	U	39	U	39	U	39	U	39	U	39	U	80	U	1.00	U
MH1-SD507	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.15	J
MH1-SD508	OUTER	51	U	100	U	51	U	51	U	53		30	J	51	U	83		1.03	
MH1-SD508DP	OUTER	50	U	100	U	50	U	50	U	50	U	160		50	U	160		0.80	J
MH1-SD509	OUTER	53	U	110	U	53	U	53	U	130		63	J	53	U	193		1.63	
MH1-SD510	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.21	J
MH1-SD511	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.30	J
MH1-SD512	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.11	J
MH1-SD513	INNER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.35	J
MH1-SD514	OUTER	70	U	140	U	70	U	70	U	570	J	560		70	U	1130		5.94	
MH1-SD515	OUTER	52	U	110	U	52	U	52	U	93	J	31	J	52	U	124		2.16	
MH1-SD516	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.22	J
MH1-SD516DP	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.14	J
MH1-SD517	OUTER	47	U	96	U	47	U	47	U	47	U	47	U	47	U	96	U	0.26	J
MH1-SD518	INNER	42	R	85	R	42	R	42	R	42	R	42	R	42	R	85	U	0.19	J
MH1-SD519	OUTER	45	U	92	U	45	U	45	U	98	J	87		23	J	208		0.65	J
MH1-SD520	OUTER	47	U	96	U	47	U	47	U	140	J	160		47	U	300		0.77	J
MH1-SD521	OUTER	47	U	96	U	47	U	47	U	47	U	47	U	47	U	96	U	0.22	J
MH1-SD522	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.25	J
MH1-SD523	OUTER	46	U	93	U	46	U	46	U	46	U	46	U	46	U	93	U	0.53	J
MH1-SD524	OUTER	43	U	87	U	43	U	43	U	43	U	19	J	43	U	19		0.25	J
MH1-SD525	OUTER	51	U	100	U	51	U	51	U	51	U	51	U	51	U	51	U	0.85	J
MH1-SD526	OUTER	48	U	97	U	48	U	48	U	48	U	48	U	48	U	97	U	0.28	J
MH1-SD527	OUTER	43	U	87	U	43	U	43	U	43	U	43	U	43	U	87	U	0.31	J
MH1-SD528	OUTER	43	U	87	U	43	U	43	U	27	J	43	U	43	U	27		0.35	J
MH1-SD529	OUTER	46	U	94	U	46	U	46	U	46	U	46	U	46	U	94	U	0.42	J
MH1-SD530	OUTER	45	U	92	U	45	U	45	U	45	U	45	U	45	U	92	U	0.22	J
MH1-SD531	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.12	J
MH1-SD532	OUTER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.26	J
MH1-SD532DP	OUTER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.17	J
MH1-SDA1	OUTER	44	U	89	U	44	U	44	U	44	U	44	U	44	U	89	U	0.53	J
MH1-SDA2	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.70	J
MH1-SDB1	RIVER	40	U	82	U	40	U	40	U	40	U	40	U	40	U	82	U	0.15	J
MH1-SDB2	RIVER	41	U	83	U	41	U	41	U	41	U	41	U	41	U	83	U	0.22	J
MH1-SDB2-DP	RIVER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.12	J
MH1-SDC1	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.13	J
MH1-SDC2	INNER	42	U	85	U	42	U	42	U	42	U	42	U	42	U	85	U	0.23	J
MH1-SDD1	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.37	J
MH1-SDD2	OUTER	41	U	84	U	41	U	41	U	41	U	41	U	41	U	84	U	0.19	J
MH1-SDE1	OUTER	54	U	110	U	54	U	54	U	54	U	610		54	U	610		3.41	J
MH1-SDE2	OUTER	42	U	86	U	42	U	42	U	42	U	42	U	42	U	86	U	0.34	J

Table A-4 (Continued)
Sediment Data (All Locations)
Manistique Harbor and River Site
Manistique, Michigan

All Concentrations in ug/kg

Sed1016	Aroclor 1016 concentration
Sed1016Q	Data qualifier for Aroclor 1016
Sed1221	Aroclor 1221 concentration
Sed1221Q	Data qualifier for Aroclor 1221
Sed1232	Aroclor 1232 concentration
Sed1232Q	Data qualifier for Aroclor 1232
Sed1242	Aroclor 1242 concentration
Sed1242L	Detection limit for Aroclor 1242
Sed1242Q	Data qualifier for Aroclor 1242
Depth	Water depth

Sed1248	Aroclor 1248 concentration
Sed1248L	Detection limit for Aroclor 1248
Sed1248Q	Data qualifier for Aroclor 1248
Sed1254	Aroclor 1254 concentration
Sed1254Q	Data qualifier for Aroclor 1254
Sed1260	Aroclor 1260 concentration
Sed1260Q	Data qualifier for Aroclor 1260
SedPCB	Total PCBs
Area	Sample location in the AOI (area of interest) or BZ (background zone)
RIO	Sample location in river, inner harbor, or outer harbor
TOC	Total organic carbon
TOCQ	Data qualifier for TOC

APPENDIX B

ERED Summary

Table B-1
Environmental Residue-Effects Database Results for PCBs in Fish Tissue
Manistique Harbor and River Site
Manistique, Michigan

Year	Author	Publication Source	Species Scientific Name	Species Common Name	Analyte Name	Conc_Wet	Conc_Units	Effect Class	Toxicity Measure	Exposure Route	Species Body Part	Species Start Lifestage	Species Habitat	Species Feeding Behavior	Comments
2003	Powell DB, RC Palm Jr, A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.98	MG/KG	Mortality	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Bacterial challenge. Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.16	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Vaccinated bacterial challenge. NOED growt (Length, weight)Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.74	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Vaccinated bacterial challenge. NOED conditior factor. Testing conditions mimic field conditions of out-migration through Duwamish waterway throug Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.95	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Challenge #2: Aquired disease resistence. NOEI growth (weight, length) Testing conditions mimic field conditions of out-migration through Duwamis waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.95	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Challenge #2: Aquired disease resistence. NOED growth condition factor (k). Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytschi	Salmon - Chinool	Aroclor 1254	0.95	MG/KG	Physiologica	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending a large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adu insects; small fish, invertebrates	Challenge #2: Aquired disease resistence. NOEI immunocompetence. Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.58	MG/KG	Cellular	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	19	MG/KG	Cellular	ED181	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Cellular	LOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.1	MG/KG	Cellular	ED18	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Mortality	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 -
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.1	MG/KG	Mortality	LD07	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - no significance calculated
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.9	MG/KG	Growth	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	2.7	MG/KG	Growth	ED59	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Reproduction	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Ovary weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.1	MG/KG	Reproductior	ED47	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Ovary weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.9	MG/KG	Physiologica	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Liver weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Physiologica	ED59	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Liver weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	19	MG/KG	Cellular	LOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Cellular	ED04	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	2.7	MG/KG	Cellular	ED45	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 93, 104, 112, 115, 126, 143, 153, 169, 184, 193 - Hepatic EROD activity
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.1	MG/KG	Mortality	LOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - no significanch calculated
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	2.7	MG/KG	Mortality	LD18	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - no significance calculated
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-6	Danio reric	Zebra Danic	PCBs	0.14	MG/KG	Growth	LOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio reric	Zebra Danic	PCBs	1.9	MG/KG	Reproductior	NOED	Ingestion	Whole Body	Adult	Not Specifiec	Not Specifiec	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Ovary weight
1998	Orn, S., P.L. Anderson, L. Fortin, M. Tysklind, L. Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio rerio	Zebra Danio	PCBs	1.1	MG/KG	Reproduction	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Ovary weight

Table B-1
Environmental Residue-Effects Database Results for PCBs in Fish Tissue
Manistique Harbor and River Site
Manistique, Michigan

Year	Author	Publication Source	Species Scientific Name	Species Common Name	Analyte Name	Conc_Wet	Conc_Units	Effect Class	Toxicity Measure	Exposure Route	Species Body Part	Species Start Lifestage	Species Habitat	Species Feeding Behavior	Comments
2001	Palace, V.P., S.M. Allen-Gil, S.B. Brown, R.E. Evans, D.A. Metner, D.H. Landers, L.R. Curtis, J.F. Klaverkamp, C.L. Baron, W. L. Lockhart	Chemosphere 45:185-19	Thymallus arcticus	Arctic Grayling	PCB 77	1.68	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Not Specifiec	Not Specifiec	Length
1976	Hansen LG, WB Wiekhurst, J Simor	J Fish Res Board Can 33:1343-135	Ictalurus punctatus	Catfish-Channe	Aroclor 1242 or PCB 124	2.172	MG/KG	Physiologica	ED120	Ingestion	Whole Body	Fingerling	Rapid water streams	Omnivore	Liver Weight Increase Whole Body Minus Stomach and Contents Fed 20 Ug/g dose at 3% body wt. 1x per day. Day 84, 12 control fish died due to pump/drain failure. Feeding of experimentals disrupted days 140-196 - all fed control food for this duration.
1976	Hansen LG, WB Wiekhurst, J Simor	J Fish Res Board Can 33:1343-135	Ictalurus punctatus	Catfish-Channe	Aroclor 1242 or PCB 124	2.172	MG/KG	Morphology	NOED	Ingestion	Whole Body	Fingerling	Rapid water streams	Omnivore	Tissue Pathologies Whole Body Minus Stomach and Contents Fed 20 Ug/g dose at 3% body wt. 1x per day. Day 84, 12 control fish died due to pump/drain failure. Feeding of experimentals disrupted days 140-196 - all fed control food for this duration.
1976	Hansen LG, WB Wiekhurst, J Simor	J Fish Res Board Can 33:1343-135	Ictalurus punctatus	Catfish-Channe	Aroclor 1242 or PCB 124	2.172	MG/KG	[illegible]	NOED	Ingestion	Whole Body	Fingerling	Rapid water streams	Omnivore	Whole Body Minus Stomach and Contents Fed 20 Ug/g dose at 3% body wt. 1x per day. Day 84, 12 control fish died due to pump/drain failure. Feeding of experimentals disrupted days 140-196 - all fed control food for this duration.
1976	Hansen LG, WB Wiekhurst, J Simor	J Fish Res Board Can 33:1343-135	Ictalurus punctatus	Catfish-Channe	Aroclor 1242 or PCB 124	2.172	MG/KG	Physiologica	NOED	Ingestion	Whole Body	Fingerling	Rapid water streams	Omnivore	Kidney Weight Whole Body Minus Stomach and Contents Fed 20 Ug/g dose at 3% body wt. 1x per day. Day 84, 12 control fish died due to pump/drain failure. Feeding of experimentals disrupted days 140-196 - all fed control food for this duration.
1976	Hansen LG, WB Wiekhurst, J Simor	J Fish Res Board Can 33:1343-135	Ictalurus punctatus	Catfish-Channe	Aroclor 1242 or PCB 124	2.172	MG/KG	Physiologica	NOED	Ingestion	Whole Body	Fingerling	Rapid water streams	Omnivore	Brain Weight Whole Body Minus Stomach and Contents Fed 20 Ug/g dose at 3% body wt. 1x per day. Day 84, 12 control fish died due to pump/drain failure. Feeding of experimentals disrupted days 140-196 - all fed control food for this duration.
1974	Lieb, A.J., D.D. Bills, and R.O. Sinnhuber	J. Agr. Food Chem., 22(4):638-642	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	8.2	MG/KG	Cellular	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	No evidence of histopathologic changes in the liver.
1974	Lieb, A.J., D.D. Bills, and R.O. Sinnhuber	J. Agr. Food Chem., 22(4):638-642	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	8.2	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	No significant difference in total weight or liver:body weight ratio.
1974	Lieb, A.J., D.D. Bills, and R.O. Sinnhuber	J. Agr. Food Chem., 22(4):638-642	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	8.2	MG/KG	Mortality	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	No increase in mortality
1974	Lieb, A.J., D.D. Bills, and R.O. Sinnhuber	J. Agr. Food Chem., 22(4):638-642	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	8.2	MG/KG	Physiologica	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	No significant difference in lipid conten
1975	Nestel H, Budd .	Can J Comp Med 39:208-21	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	81	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	
1975	Nestel H, Budd .	Can J Comp Med 39:208-21	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	81	MG/KG	Survival	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	
1975	Nestel H, Budd .	Can J Comp Med 39:208-21	Oncorhynchus mykiss	Trout - Rainbow	Aroclor 1254	81	MG/KG	Survival	NOED	Ingestion	Whole Body	Juvenile	Cool streams	Carnivore-juv fish, inverts	
1978	Addison RF, ME Zinck, DE Wills	Comp Biochem Physiol 61C:323-32	Salvelinus fontinalis	Trout - Brook	Aroclor 1254	38.86	MG/KG	Physiologica	ED170	Ingestion	Fillet	Immature	Cool streams, gravel bottoms	Carnivore-aquatic insects, fish	O-de-ethylase activity
1978	Addison RF, ME Zinck, DE Wille	Comp Biochem Physiol 61C:323-32	Salvelinus fontinalis	Trout - Brook	Aroclor 1254	38.86	MG/KG	Physiologica	ED170	Ingestion	Fillet	Immature	Cool streams, gravel bottoms	Carnivore-aquatic insects, fish	O-de-ethylase activity
1978	Addison, R.F., M.E. Zinck and D.E. Wills	Comp. Biochem. Physiol. 61c:323-32	Salvelinus fontinalis	Trout - Brook	Aroclor 1254	39	MG/KG	Biochemics	LOED	Ingestion	Fillet	Immature	Cool streams, gravel bottoms	Carnivore-aquatic insects, fish	7 Doses Over 18-day Period; Effect At Only Exposure Dose: Hepatic Enzyme Induction
1978	Addison, R.F., M.E. Zinck and D.E. Wills	Comp. Biochem. Physiol. 61c:323-32	Salvelinus fontinalis	Trout - Brook	Aroclor 1254	39	MG/KG	Growth	NOED	Ingestion	Fillet	Immature	Cool streams, gravel bottoms	Carnivore-aquatic insects, fish	7 Doses Over 18-day Period; Growth as total body weight and liver weight as % of body weight
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ Toxicol. & Chem	Oncorhynchus tshawytscha	Salmon - Chinook	Aroclor 1254	60	MG/KG	Mortality	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending all large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adult insects; small fish, invertebrates	Initial LD50 test at 3, 10.7, 40, 107, 400 & 800 mg/kg bw. No mortality; LD50 couln't be calculated Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem	Oncorhynchus tshawytscha	Salmon - Chinook	Aroclor 1254	0.16	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending all large streams, e.g., Columbia River	Feeds on variety of forms, e.g., larval, adult insects; small fish, invertebrates	Innate disease response. NOED growth - length or weight.Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound
2003	Powell DB, RC Palm Jr. A Skillman, K Godtfredsen	Environ.Toxicol. & Chem.	Oncorhynchus tshawytscha	Salmon - Chinook	Aroclor 1254	0.95	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	Both coasts of Pacific; Monterey Bay and China north to Bering Straits, ascending all large streams, e.g., Columbia River	Feeds on variety of forms e.g., larval, adult insects; small fish, invertebrates	Innate disease response. NOED Condition factor (k).Testing conditions mimic field conditions of out-migration through Duwamish waterway through Puget Sound

Table B-1
Environmental Residue-Effects Database Results for PCBs in Fish Tissue
Manistique Harbor and River Site
Manistique, Michigan

Year	Author	Publication Source	Species Scientific Name	Species Common Name	Analyte Name	Conc_Wet	Conc_Units	Effect Class	Toxicity Measure	Exposure Route	Species Body Part	Species Start Lifestage	Species Habitat	Species Feeding Behavior	Comments
1998	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio rerio	Zebra Danio	PCBs	2.7	MG/KG	Reproduction	ED54	Ingestion	Whole Body	Adult	Not Specified	Not Specified	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Ovary weight
1998	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio rerio	Zebra Danio	PCBs	0.14	MG/KG	Physiologica	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Liver weight
1998	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio rerio	Zebra Danio	PCBs	1.1	MG/KG	Physiologica	ED09	Ingestion	Whole Body	Adult	Not Specified	Not Specified	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Liver weight
1998	Orn, S., P.L. Anderson, L. Forlin, M. Tysklind, L Norrgren	Arch Environ Contam Toxicol 35:53-5	Danio rerio	Zebra Danio	PCBs	2.7	MG/KG	Physiologica	ED09	Ingestion	Whole Body	Adult	Not Specified	Not Specified	PCBs 41, 51, 60, 68, 91, 99, 104, 112, 115, 126 143, 153, 169, 184, 193 - Liver weight
1977	Mayer, F.L., P.M. Mehrle, and H.O. Sanders	Arch. Environ. Contam. 5:501-51	Oncorhynchus kisutch	Salmon-coho	PCBs	545	MG/KG	Mortality	ED100	Ingestion	Whole Body	Immature	NW America and Asian Coast. Streams in Spring, Fall	Carnivore-aquatic insects, fish, invert	Radiolabeled - Contam. Food Fed
1976	Hansen, L.G., W.B. Wiekhorst and J. Simo[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	MG/KG	Growth	LOED	[illegible]	Whole Body	Immature	Rapid water streams	Omnivore	[illegible]
1976	Hansen, L.G., W.B. Wiekhorst and J. Simon	J. Fish. Res. Bd. Can. 33:1343-1352	Ictalurus punctatus	Catfish-Channel	PCBs	10.9	MG/KG	Cellular	NOED	Ingestion	Whole Body	Immature	Rapid water streams	Omnivore	No evidence of histopathology in liver, brain kidney, reproductive tract, gills, gastrointestinal system, or muscle.
1976	Hansen, L.G., W.B. Wiekhorst and J. Simon	J. Fish. Res. Bd. Can. 33:1343-1352	Ictalurus punctatus	Catfish-Channel	PCBs	14.3	MG/KG	Cellular	NOED	Ingestion	Whole Body	Immature	Rapid water streams	Omnivore	No evidence of histopathology in liver, brain kidney, reproductive tract, gills, gastrointestinal system, or muscle. Residue in whole body minus offal.
1976	Hansen, L.G., W.B. Wiekhorst and J. Simon	J. Fish. Res. Bd. Can. 33:1343-1352	Ictalurus punctatus	Catfish-Channel	PCBs	10.9	MG/KG	Mortality	NOED	Ingestion	Whole Body	Immature	Rapid water streams	Omnivore	No Effect On Mortality
1976	Hansen, L.G., W.B. Wiekhorst and J. Simon	J. Fish. Res. Bd. Can. 33:1343-1352	Ictalurus punctatus	Catfish-Channel	PCBs	14.3	MG/KG	Mortality	NOED	Ingestion	Whole Body	Immature	Rapid water streams	Omnivore	No Effect On Mortality
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	170	MG/KG	Reproduction	ED83	Ingestion	Whole Body	Adult	Not Specified	Not Specified	83% Reduction in hatchability of eggs. Residue measured 2 months before spawning.
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	1.6	MG/KG	Behavior	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	Non-significant impairment of swimming performance; changes in feeding and social behavior.
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	180	MG/KG	Growth	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	Significantly increased growth at 79 days. Residue measured at 82 days.
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	70	MG/KG	Mortality	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	Doubling Of Mortality Rate Compared To Controls After 300 Days
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	15	MG/KG	Reproduction	LOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	Reduction in time to hatch. Fry death within 1 week of hatching. Spawning induced at higher water temperatures. Residues measured 2 months before spawning.
1980	Bengtsson, B.E.	Water Res. 14:681-687	Phoxinus phoxinus	Minnow	PCBs	1.6	MG/KG	Reproduction	NOED	Ingestion	Whole Body	Adult	Not Specified	Not Specified	No significant reduction in time to hatch. Residue measured 2 months before spawning.
1983	Westin, D.T., Olney, C.E., Rogers, B.A	Bull. Environm. Contam. Toxicol. 30: 50-57	Morone saxatilis	Striped Bass	PCBs	4.4	MG/KG	Growth	NOED	Ingestion	Whole Body	Larval	Inshore fish in various habitats in estuaries and rivers	Voracious, smaller fish, crustaceans, shellfish	No significant difference in length and weight gain in larva. Parents exposed to PCBs in field. Residue in eggs of 8.1 mg/kg. PCB diet started after yolk absorption.
1976	Gruger, E.H., T. Hurley and N.L. Karrick	[illegible]	[illegible]	[illegible]	PCBs	[illegible]	MG/KG	Growth	LOED	[illegible]	Whole Body	Juvenile	NW America and Asian Coast Streams in Spring, Fall	Carnivore-aquatic insects, fish, invert	[illegible]
1976	Gruger, E.H., T. Hurley and N.L. Karrick	Environ. Sci. Technol. 10:1033-1037	Oncorhynchus kisutch	Salmon-coho	PCBs	0.6	MG/KG	Growth	NOED	Ingestion	Whole Body	Juvenile	NW America and Asian Coast. Streams in Spring, Fall	Carnivore-aquatic insects, fish, invert	No Effect On Growth (weight gain
1988	Opperhuizen A, SM Schrap	Chemosphere 17:253-262	Poecilia reticulata	Guppy	PCB 197	2.6	MG/KG	Mortality	LD22	Ingestion	Whole Body	Adult	Native to West Indies, n. South America, est. in AB, AZ, ID, NV, TX, WY, possibly CA; generally uncommon	Feeds on detritus, small invertebrates	
1988	Opperhuizen A, SM Schrap	Chemosphere 17:253-262	Poecilia reticulata	Guppy	PCB 133	2.6	MG/KG	Mortality	LD22	Ingestion	Whole Body	Adult	Native to West Indies, n. South America, est. in AB, AZ, ID, NV, TX, WY, possibly CA; generally uncommon	Feeds on detritus, small invertebrates	
2001	MB Matta, J Linse, C Cairncross, L Francendese, RM Kocan	Environ Tox & Chem 20(2):327-335	Fundulus heteroclitus	Mummichog	Aroclor 1268	14	MG/KG	Reproduction	NOED	Ingestion	Whole Body	Adult	Sheltered shores, tidal creeks, brackish water at mouths of streams and estuaries	Omnivore-diatoms, small crustaceans, mollusks, sometimes small fish	Resd measurement basis not given, assumed to be wet weight
2001	MB Matta, J Linse, C Cairncross, L Francendese, RM Kocan	Environ Tox & Chem 20(2):327-335	Fundulus heteroclitus	Mummichog	Aroclor 1268	15	MG/KG	Survival	NOED	Ingestion	Whole Body	Adult	Sheltered shores, tidal creeks, brackish water at mouths of streams and estuaries	Omnivore-diatoms, small crustaceans, mollusks, sometimes small fish	Resd measurement basis not given, assumed to be wet weight.
2001	MB Matta, J Linse, C Cairncross, L Francendese, RM Kocan	Environ Tox & Chem 20(2):327-335	Fundulus heteroclitus	Mummichog	Aroclor 1268	15	MG/KG	Growth	NOED	Ingestion	Whole Body	Adult	Sheltered shores, tidal creeks, brackish water at mouths of streams and estuaries	Omnivore-diatoms, small crustaceans, mollusks, sometimes small fish	Resd measurement basis not given, assumed to be wet weight.

Source: U.S. Army Corps of Engineers/U.S. Environmental Protection Agency Environmental Residue-Effects Database (ERED), 2004. (http://www.wes.army.mil/el/ered)
Shaded values indicate selected TRVs

APPENDIX C

Toxicological Profile for PCBs

APPENDIX C

TOXICOLOGICAL PROFILE FOR PCBs

The following toxicological information on PCBs was obtained from Eisler, R. 1986. *Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: a synoptic review.* U.S. Fish and Wildlife Service Biological Report 85(1.7).

PCBs are organic compounds commercially produced by chlorination of a biphenyl (BP) with anhydrous chlorine in the presence of iron filings or ferric chloride as the catalyst. Because of their wide range of physical properties, their chemical stability, and their miscibility with organic compounds, PCBs have been used extensively as hydraulic fluids, plasticizers, adhesives, heat transfer fluids, wax extenders, dedusting agents, lubricants, flame retardants, and especially as dielectric fluids in capacitors and transformers. The current uses of PCBs in the United States have been severely curtailed and production was stopped during the 1970's, although significant quantities of PCBs are still used as dielectric fluids in older transformers and capacitors.

PCBs are extremely stable compounds, and slow to chemically degrade under environmental conditions. The behavior of PCB mixtures in the environment is directly correlated to the degree of chlorination. PCBs are now distributed worldwide, with measurable concentrations reported in aquatic organisms and wildlife from North America, Europe, the United Kingdom, and the Atlantic and Pacific Ocean. PCBs tend to bond tightly to particulate matter, notably soils and sediments of lakes, estuaries, and rivers, where they may remain available for resuspension for at least 8 to 15 years.

PCBs presence in organisms has been shown to cause reproductive failure, birth defects, skin lesions, tumors, liver disorders, and, among sensitive species, death. Interspecies differences in sensitivity to PCBs are large, even between species that are closely related taxonomically. PCB toxicity is further enhanced by their ability to bioaccumulate and to biomagnify within the food chain due to extremely high liposolubility. The toxicological properties of individual PCBs are influenced primarily by two factors: the partition coefficient based on solubility in N-octanol/water (Kow); and steric factors, resulting from different patterns of chlorine substitution. In general, PCB isomers with high Kow values, and high numbers of substituted chlorines in adjacent positions, constitute the greatest environmental concern.

For aquatic life, water concentrations of less than 0.014 ug total PCBs/1 (ppb) appear to afford a satisfactory degree of protection, although concentrations as low as 0.006 ug/l resulted in measurable accumulation by various species of filter-feeding shellfish. In aquatic systems, toxicity increased with increasing exposure, crustaceans and younger developmental stages were the most sensitive groups tested, and lower chlorinated biphenyls were more toxic than higher chlorinated biphenyls. Among sensitive species of teleosts, total PCB residues (in ug/kg fresh weight) in excess of 500 in diets, 400 in whole body, and 300 in eggs were demonstrably harmful, and should be considered as presumptive evidence of significant PCB contamination.

Aquatic invertebrates assume an important role in the cycling of PCBs within and between ecosystems. Uptake of PCBs from the sediment by chironomid (*Chironomus plumosus* - type) larvae has been directly related to the concentration of PCBs in the sediment. When larvae metamorphosed to adults, PCB compounds were concentrated and transferred from the aquatic to the terrestrial environment. Terrestrial predators that feed on emerging aquatic insects whose larval stage inhabits PCB-contaminated sediments may be exposed to PCBs.

Among small mammals, the mink (*Mustela vison*) is one of the most susceptible species tested; dietary levels as low as 100 ug PCBs/kg fresh weight caused death and reproductive toxicity. A tolerable daily limit for mink has been estimated at less than 1.5 ug total PCBs/kg body weight. PCBs can be transferred to young mammals either transplacentally or in breast milk. Retention of PCBs is highly species specific: nonhuman primates, for example, retained PCBs more efficiently than rodents Tolerable daily PCB levels for rhesus monkey (*Macaca mulatta*), dog (*Canis* sp.), and rat (*Rattus* spp.) were 1.0, 2., and 5.0 ug/kg body weight, respectively. As a group, birds were more resistant to acutely toxic effects of PCBs than mammals. For birds, total PCB levels (in ug/kg fresh weight) in excess of 3,000 in diet, 16,000 in egg, or 54,000 in brain were frequently associated with PCB poisoning.