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EPA Sediment Assessment Of Hotspot Areas In The Duluth/Superior Harbor

Minnesota Pollution Control Agency

SEDIMENT ASSESSMENT OF HOTSPOT AREAS IN THE DULUTH/SUPERIOR HARBOR

Submitted to

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LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
$AgNO_3$	Silver Nitrate
AOC	Area of Concern
AR	Analytical Replicate
As	Arsenic
ASTM	American Society of Testing and Materials
AVS	Acid Volatile Sulfide
Cd	Cadmium
cm	Centimeter
CMD	Classical Multi-dimensional Scaling
Co	Company
Cu	Copper
CV	Coefficient of Variation
DM&IR	Duluth, Masabe, and Iron Range
DMIR	DM&IR Stockpile
DSD	Duluth Steam District
EPA	Environmental Protection Agency
ER	Extraction Replicate
ERP	Erie Pier
Fe	Iron
ft	Feet
GC/ECD	Gas Chromatography/Electron Capture Detection
GC/MS	Gas Chromatography/Mass Spectrometry
GIS	Geographic Information System
GLNPO	Great Lakes National Program Office
GPS	Global Positioning System
Hg	Mercury
HOB	Howard's Bay
IJC	International Joint Commission
KCl	Potassium Chloride
kg	Kilogram
KMB	Kimball's Bay
LEL	Lowest Effect Level
LOD	Limit of Detection
LOQ	Limit of Quantitation
LSRI	Lake Superior Research Institute
m	Meter
mg	Milligram
MLH	M.L. Hibbard/DSD No. 2 and Grassy Point area
mm	Millimeter
MN	Minnesota

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

MNS	Minnesota Slip
MPCA	Minnesota Pollution Control Agency
N	North
N/A	Not Applicable
ND	Not Detected
NEL	No Effect Level
NH_3	Ammonia
Ni	Nickel
NRRI	Natural Resources Research Institute
NOAA	National Oceanographic and Atmospheric Administration
NQ	Not Quantifiable
OC	Organic Carbon
OMOEE	Ontario Ministry of Environment and Energy
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PCB	Polychlorinated Biphenyl
PDOP	Position Dilution of Precision
PPDC	Post Process Differential Correction
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAP	Remedial Action Plan
RCF	Relative Contamination Factor
R-EMAP	Regional Environmental Monitoring and Assessment Program
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
RTR	Ratio-to-Reference Value
R/V	Research Vessel
SA	Selective Availability
SD	Standard Deviation
SEL	Severe Effect Level
SEM	Simultaneously Extractable Metals
SOP	Standard Operating Procedure
SQG	Sediment Quality Guideline
STP	Sewage Treatment Plant
SUS	Slip C
TCDD	Tetrachlorodibenzo-p-dioxin (as in 2,3,7,8-TCDD)
TCDF	Tetrachlorodibenzofuran (as in 2,3,7,8-TCDF)
TOC	Total Organic Carbon

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

µg	Microgram
UMD	University of Minnesota-Duluth
UWS	University of Wisconsin-Superior
VC	Vibrocorer
W	West
WDNR	Wisconsin Department of Natural Resources
WI	Wisconsin
WLS	WLSSD/Coffee and Miller Creek Bay
WLSSD	Western Lake Superior Sanitary District
wt.	Weight
WWTP	Wastewater Treatment Plant
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The St. Louis River and the Duluth/Superior Harbor consist of a variety of habitat types, ranging in character from relatively pristine streams and wetlands to an industrialized harbor containing two Superfund sites. Many current and former dischargers have contributed to the contamination of sediments within this Area of Concern (AOC). Currently, there are only a few permitted point source discharges to the waters of the AOC. These include (in Minnesota): the Western Lake Superior Sanitary District (WLSSD), which collects and treats both municipal and industrial wastes for the entire region of the AOC from Cloquet to Duluth. In Wisconsin, current major NPDES dischargers to the waters of the AOC include the Superior Municipal Wastewater Treatment Plant (WWTP), Murphy Oil-Superior Refinery, and Superior Fiber Products (whose wastewater is transported to WLSSD for treatment).

The geological setting, anthropological history, and recent environmental knowledge about the AOC are documented in the Stage I Remedial Action Plan (RAP) document [Minnesota Pollution Control Agency (MPCA)/Wisconsin Department of Natural Resources (WDNR), 1992]. During the past five years, the MPCA and its collaborators have been actively involved in delineating the extent of sediment contamination in the St. Louis River AOC. These studies include:

- Preliminary assessment of contaminated sediments and fish in the Thomson, Forbay, and Fond du Lac Reservoirs (Schubauer-Berigan and Crane, 1996)

- Survey of sediment quality in the Duluth/Superior Harbor: 1993 sampling results (Schubauer-Berigan and Crane, 1997)

- Sediment assessment of hotspot areas in the Duluth/Superior Harbor (this report)

- Regional Environmental Monitoring and Assessment Program (R-EMAP) surveying, sampling, and testing: 1995 and 1996 sampling results [draft report in process of being prepared by the MPCA, Natural Resources Research Institute (NRRI), and U.S. Environmental Protection Agency (EPA)]

- Sediment remediation scoping project at Slip C in the Duluth Harbor (report to be prepared by the MPCA during the spring of 1998)

- Development of sediment quality guidelines for the St. Louis River AOC (new project begun October 1, 1997)

- Bioaccumulation of contaminants in the Duluth/Superior Harbor (new project begun October 1, 1997).

The above investigations have been, or are being, conducted with the cooperation and financial support of the U.S. EPA. These studies will support the assessment and hotspot management plan goals of the Phase I sediment strategy for the RAP. The chemistry data from most of these investigations are being entered into two similar, but separate, geographic information system (GIS)-based databases for the Duluth/Superior Harbor. The databases are maintained by the U.S. Army Corps of Engineers and EPA's Great Lakes National Program Office (GLNPO).

In this report, the results of the 1994 sediment assessment of hotspot areas in the Duluth/Superior Harbor will be presented. Due to the large number of figures and tables in this report, all of them have been moved to the end of this report.

1.2 PROJECT DESCRIPTION

A general assessment of sediment contamination in the Duluth/Superior Harbor was conducted during 1993. The results of this MPCA investigation indicated that polycyclic aromatic hydrocarbon (PAH) contamination was widespread throughout the harbor (Schubauer-Berigan and Crane, 1997). Heavy metal, mercury, selected pesticide, and polychlorinated biphenyl (PCB) contamination was also of concern at several sites. The Duluth portion of the harbor was generally more contaminated than the Superior portion of the harbor (Figure 1-1).

The USX Superfund site was the most contaminated site evaluated in the 1993 sediment survey (Schubauer-Berigan and Crane, 1997). This site, along with the Interlake/Duluth Tar Superfund site, have been undergoing additional investigations as part of the potentially responsible parties legal obligations. Other sites that were rated highly for further study included: Hog Island Inlet and Newton Creek, the bay surrounding WLSSD and Coffee/Miller Creek outfalls, Fraser Shipyards, Minnesota Slip, area between the M.L. Hibbard Plant/Duluth Steam District (DSD) No. 2 and Grassy Point, and in the old 21st Ave. West Channel. Other areas, such as Slip C and off the city of Superior wastewater treatment plant (WWTP) outfall, were listed as medium priority. It is important to note that this 1993 study was limited in scope and was not meant to characterize large areas as to the extent of contamination.

The results of the 1993 sediment survey were used to shape the scope of this project. The MPCA, in cooperation with GLNPO and WDNR, conducted a sediment survey of the following hotspot areas during the fall of 1994:

- Bay south of the DM&IR taconite storage facility

- Bay east of Erie Pier
- Howard's Bay (including Fraser Shipyards)
- Area north of Grassy Point and in the vicinity of M.L. Hibbard/DSD No. 2
- Minnesota Slip
- City of Superior WWTP
- Slip C
- WLSSD, Miller Creek, and Coffee Creek Embayment
- Kimball's Bay (reference site).

The two Superfund sites and the Hog Island Inlet/Newton Creek sites were not included in this study due to other in-depth investigations that were already underway at these sites. Two sites that were ranked low priority for further study in the 1993 sediment investigation were included in this survey. Erie Pier was included because of acute sediment toxicity that was observed at the 1993 sample site. DM&IR was included to confirm the 1993 observation that this site was not very contaminated.

A sediment quality triad approach (Long and Chapman, 1985) was used in this study to characterize sediment quality at each site. Synoptic measures of sediment chemistry, sediment toxicity, and benthological community structure were made at selected sites. A short-list of contaminants was measured in various core sections based on the results of the 1993 sediment survey. Ten-day sediment toxicity tests, using *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*), were used to assess biological effects under controlled conditions. The benthological community structure was used to assess *in situ* biological effects. Sediments that demonstrated a high degree of concordance among all three measures were considered to have degraded sediment quality and pose a risk to the environment. Sediments that showed concordance between two of the three measures may or may not be degraded and warrant further investigation.

1.3 PROJECT OBJECTIVES

The primary objectives of this investigation were to:

- Perform site-specific assessments of sediment contamination, toxicity, and benthic community structure at areas identified during the 1993 sediment survey as having elevated contamination. A similar Triad assessment was performed at a reference site (i.e., Kimball's Bay).

- Develop a sediment management plan for study sites where the presence of contaminants are associated with toxicity and/or impaired benthic communities.

1.4 PROJECT TASKS

Specific project tasks included the following:

- Measure concentrations of selected contaminants at eight contaminated sites, and one reference site, in the Duluth/Superior Harbor. Contaminants of concern included: PCBs, PAHs, PAH screen, TCDD and TCDF, mercury, lead, arsenic, simultaneously extractable metals (SEM) (i.e., cadmium, copper, nickel, lead, and zinc), and ammonia. In addition, total organic carbon (TOC), acid volatile sulfide (AVS), and particle size were measured.

- Perform sediment toxicity tests with *H. azteca* (10-day survival) and *C. tentans* (10-day survival and growth) at half of the locations within each site (selected on a worst-case basis) using EPA-developed methodologies.

- Conduct a benthic community assessment at each site by sampling macrobenthos at all of the locations within each site, identifying organisms to the lowest possible classification, and using community evaluation metrics to determine the ecological status of the benthic community.

- Use the sediment quality triad approach to integrate chemistry, toxicity, and benthic community assessment data.

- Develop sediment management plans for areas with contaminated sediments in the Duluth/Superior Harbor.

CHAPTER 2

METHODS

2.1 FIELD METHODS

2.1.1 Reconnaissance Survey and Site Selection

The sites examined in this study were located in the St. Louis River and Duluth/Superior Harbor, downstream of the Kimball's Bay area (Figure 2-1). General site selection resulted from analysis of the data from the 1993 Duluth/Superior Harbor sediment survey (Schubauer-Berigan and Crane, 1997). Contaminated sites were also selected in consultation with WDNR and GLNPO sediment personnel. The area of Kimball's Bay was selected as a “clean” reference site for the eight hotspot areas in the Duluth/Superior Harbor.

A stratified random sampling approach was used for final site selection within each of the nine areas. Sampling locations were obtained by placing a grid (of a size appropriate to generate the desired number of samples at each site) over the site map. The grid size was determined by the size of the area to be sampled, as well as the complexity of contaminant sources or hydrodynamics of the site. For example, at the WLSSD and Miller and Coffee Creek embayment site, a grid size of 150 m was used to more finely distinguish the three contaminant sources. A larger grid size of 400 m was used at the M.L. Hibbard/DSD No. 2 and Grassy Point area to bracket contamination over a wider area.

During July and August of 1994, several locations to be sampled intensively during September 1994 were scoped out during reconnaissance surveys. Specifically, locations in the WLSSD and Miller/Coffee Creek embayment, the area in Howard's Bay near Fraser Shipyards, and the bay near Barker’s Island and the City of Superior WWTP were surveyed with the assistance of the WDNR survey team. In these reconnaissance surveys, the pre-selected grid points were evaluated for the suitability of the substrate for surficial sediment sampling. The geographical coordinates were surveyed by the WDNR team, and the global positioning system (GPS) coordinates were recorded by MPCA staff. All sample coordinates were recorded with a Trimble Pathfinder Basic Plus GPS. These GPS coordinates were used to revisit the sites during the actual sampling in September 1994; however, the final (official) sampling coordinates are those recorded in the field during sampling.

2.1.2 Sediment Collection

2.1.2.1 Sampling with a small MPCA boat

The bays north and south of the M.L. Hibbard/DSD No. 2 plant (MLH sites), as well as the bay south of the DM&IR taconite storage facility (DMIR sites), were sampled prior to Kimball’s Bay and the other sites in the Duluth/Superior Harbor. A small MPCA vessel was used for the field sampling. This was necessitated by the shallow water depths at these sites (i.e., 1-3 m) and/or difficulty of access (caused by anchored wood debris) experienced by the R/V Mudpuppy during the 1993 survey. The ten sites in the M.L. Hibbard Plant/DSD No. 2 and Grassy Point bays, and five sites in the DM&IR bay, were sampled during August 22-24, 1994. At each of the ten locations in the Hibbard Plant/Grassy Point bays, geographical coordinates were ascertained using a GPS unit. At each site location, a minimum of 100 data points were collected with the GPS unit while tracking at least four satellites (3D mode) with a position dilution of precision (PDOP) value of less than six. Recorded data were downloaded on a personal computer daily, and the error caused by selective availability (SA) was eliminated utilizing post process differential correction (PPDC). This process was carried out using Pfinder software version 2.54 and base files from the Minnesota Power Base Station in Duluth. These final coordinates were accurate to within 2-5 m and were used to construct site maps.

After positioning and anchoring the boat, two types of sediment core samples were collected at the MLH sites: several gravity cores, which collected the top 13.5-22 cm of sediment, and a single, long manually-driven core (collected with a Livingston corer), which collected sediment to the bottom of the soft penetrable layer (0.4-0.95 m). The shorter surficial (gravity) cores were combined to provide sufficient material for analysis of selected contaminants (Table 2-1) and where indicated, toxicity tests. In addition, three individual gravity cores collected from each location were sieved through a standard 40-mesh screen, and the residue was preserved in a formalin solution within 24 hours of collection for enumeration of the benthos. The water and soft sediment depths were measured at each site using a sediment poling device similar to that developed by the WDNR sediment team.

The gravity core samples for chemistry and toxicity were decanted of their overlying water. Next, the samples were either placed directly into a precleaned sample jar (in the case of the chemistry samples), or combined and homogenized in a large acid- and solvent-cleaned glass bowl where they were split into two, 1-L jars for toxicity testing. Each deep Livingston core was extruded on site and visually described from the surface to maximum depth. The bottom 15-27 cm section of the core was then removed from the core and placed into a 1-L glass jar for later homogenization and subsequent splitting for chemical analysis.

At the DM&IR taconite storage facility site, a Ponar sampler was used because of the presence of large amounts of taconite pellets. The pellets made the sediment too heavy to be collected with a gravity corer. Only surficial samples were collected for toxicity, benthos, and contaminant analysis. After collection with the Ponar sampler, the samples were treated similar to those from the MLH sites.

2.1.2.2 Sampling with the R/V Mudpuppy

The other sites were sampled during September 21 to October 3, 1994 using GLNPO's research vessel (R/V), the Mudpuppy. The R/V Mudpuppy is a monohull aluminum barge with an overall length of 9.2 m, a 2.4 m beam, and a draft of 0.5 m (Smith and Rood, 1994). It is designed for collecting deep cores, using a vibrocorer, in shallow areas. The sites were sampled in the following order during the fall of 1994.

- WLSSD/Miller and Coffee Creek embayment (WLS 1-20): September 21, 23, 26-27
- Slip C (SUS 1-8): September 22 and October 3
- Howard's Bay (HOB 1-15): September 27-29
- City of Superior WWTP (STP 1-12): September 29-30 and October 3
- Minnesota Slip (MNS 1-5): September 30
- Erie Pier embayment (ERP 1-5): October 4
- Kimball's Bay (KMB 1-5): October 4.

The sampling protocols for core collection were the same for all sites within all locations, and are summarized as follows. The predetermined geographical coordinates were used to guide the R/V Mudpuppy to the sampling position. The GPS unit, rather than the boats Loran unit, was the device of record for locating the desired position. In all cases, positioning was confirmed by sighting the boats position with reference to visual landmarks. The R/V Mudpuppy was then triple-anchored on-site, water depth measured, sampling start time noted, and the final position recorded on the GPS unit.

The R/V Mudpuppy was accompanied by a small boat operated by researchers from the University of Wisconsin-Superior (UWS); they processed the benthos samples. Small (i.e., 5 cm diameter) gravity cores were used for sampling benthos, toxicity, and surficial chemistry samples because of their non-disruptive nature and ability to obtain a relatively undisturbed sediment-water interface. The vibrocorer was used to sample sediments deeper than 15 cm where desired. Benthos samples were collected prior to the vibrocores at each site by deploying the gravity corer one to three times per replicate (depending on the depth sampled at each general location). Three benthos sample replicates were collected at each site. The benthos core replicates were sieved in the field using a wash bucket (Wildco, Saginaw, MI) with a U.S. no. 40 mesh (425 m opening). The debris material was placed in a glass sample jar, preserved with 10% formalin solution containing rose bengal stain, and labeled. Samples were brought to the Lake Superior Research Institute (LSRI) for storage and processing on a daily basis. The number of cores per replicate and sampled depth were recorded in the study field notebook, along with a description of the sediment substrate.

After the collection of the benthos samples, several short gravity cores were obtained at each site for the surficial chemistry and toxicity samples. The number of cores collected varied by site; generally, cores were collected until sufficient volume was obtained to perform chemistry and/or toxicity analyses (i.e., about 2.5 L). The number, depth, and physical description of cores thus collected were recorded in the field notebook. The cores were decanted of overlying water and placed directly into a precleaned 1-L jar (chemistry samples). The toxicity samples were combined and homogenized in an acid- and solvent-cleaned glass mixing bowl and split into two 1-L glass jars. All samples were immediately placed on ice. At the end of each day, the samples were transferred to a storage refrigerator at the MPCA’s Duluth Regional office.

Deeper core sections for chemical analyses were obtained using the vibrocorer on board the R/V Mudpuppy. As in the 1993 sediment assessment project, a 3-m long core tube, lined with a 4-mm wall thickness butyrate core tube liner, was attached to the vibrocorer head. Cores were collected according to the standard operating procedures (SOPs) detailed in the Quality Assurance Project

Plan (QAPP) (Schubauer-Berigan, 1994) and in Smith and Rood (1994). Cores were, in general, driven to the point of refusal at each site. Core displacement and measured length were recorded. A single vibrocore sample was collected at each site.

The vibrocore was processed on board the R/V Mudpuppy immediately after collection. Before lifting anchor, the sample processing crew extruded the core on the boat deck. The core was sectioned by sawing off the top 15 cm of the core to provide the first (surficial) section. This section was discarded, because surficial sediment was analyzed using samples collected by the gravity corer. The core was then sectioned at succeeding 15 cm intervals. The sections retained for chemical analysis depended on the sampling goals, which varied from site-to-site. Table 2-1 gives the sectioning scheme for cores collected at each of the nine areas. A 15-cm section length provided sufficient sample volume (approximately 1.5 L) to perform all the analyses required for each section.

The visual characteristics of the core sections were described in the field notebook. The core section was then decontaminated by scraping away and discarding the outer 2-3 mm, using a solvent- and acid-cleaned Teflon® spatula. Individual core sections were placed into a 4-L acid- and solvent-rinsed glass container and homogenized by stirring. Homogenized core sections were placed into precleaned 1-L glass jars and left on ice while on board the R/V Mudpuppy. At the end of each day, the samples were delivered on ice to a storage refrigerator at the MPCA's Duluth Regional Office.

2.2 SAMPLE TRACKING

The benthos samples were transported to LSRI on a daily basis during field sampling. After field sampling was completed, the toxicity test samples were brought directly to the MPCA Toxicology Laboratory in St. Paul, MN where the tests were conducted. The samples were stored at 4° C in a refrigerator in a controlled access room. Within one month of field collection, most of the refrigerated core sections for chemical analysis were apportioned into precleaned jars by a MPCA technician and were delivered to the contract laboratory. The Wisconsin State Laboratory of Hygiene could not store all of the mercury samples. Thus, they requested batches of samples to be sent to them over a period of several months. All samples for chemical analyses were accompanied by sample tracking forms, which tracked the sample conditions and handling by MPCA and contract personnel.

Formal chain-of-custody procedures were not followed since the sample data were not intended to be used for enforcement purposes.

2.3 LABORATORY METHODS

Standard operating procedures (SOPs) for the chemical analyses, toxicity testing, and benthos sampling are appended to the Quality Assurance Project Plan (QAPP) for this project (Schubauer-Berigan, 1994). The methods are cited in the following sections for reference purposes.

2.3.1 Chemical Analyses

A summary of the analytical procedures used in this investigation are given in the QAPP (Schubauer-Berigan, 1994) and in Table 2-2. A PAH fluorometric screening method was used to provide a low-cost procedure for locating PAH-contaminated sediments. This method was calibrated using PAH results determined by EPA Method 8270.

2.3.2 Sediment Toxicity Tests

Sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

The toxicity tests were conducted using the procedures described in U.S. EPA (1994a). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable, mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994a). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange, while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water. Overlying water for the tests was nonchlorinated well water. The overlying water was monitored daily for pH, dissolved oxygen, and temperature.

The *Hyalella azteca* and *Chironomus tentans* tests were required to meet quality assurance (QA) requirements such as acceptable control sediment survival (i.e., mean survival of 80% for *H. azteca* and 70% for *C. tentans*), and acceptable performance on reference toxicant tests (i.e., test results within two standard deviations of the running mean). Reference toxicant tests were not performed with *C. tentans*, because they do not survive well in water-only tests.

2.3.3 Benthological Community Structure

2.3.3.1 Sample processing

Sample tracking work sheets were created for all samples, and the date and initials of the person performing the activity was entered for each step in the processing procedure. Samples were initially decanted to remove the formalin, and the debris was rinsed on a U.S. no. 40 mesh sieve (i.e., 425 m opening). The debris was either picked immediately to remove all organisms, or it was represerved with 70% ethanol for later processing. All organisms were systematically picked from the debris by placing a spoonful of debris in a large gridded petri dish, placing the dish on a light table, and viewing it under low power (i.e., 7X magnification) through a dissecting microscope with additional overhead light. The entire sample was picked in this way. The organisms were placed in 1-dram vials and preserved in 70% ethanol for later identification and long-term curation. The sample debris was placed into a properly labeled storage jar (i.e., 50 to 120 mL) for later quality control checks and long-term storage.

2.3.3.2 Enumeration of benthic invertebrates

Organisms were separated into three groups: Chironomidae/Chaoboridae/Ceratopogonidae (midges), Oligochaeta (worms), and all other invertebrates. All of the "other invertebrates" were identified by the Senior Taxonomist, Dr. Kurt L. Schmude (UWS LSRI). Empty mollusc shells were disregarded. Pieces of invertebrates were picked and counted if the piece was determined to have come from a live organism at the time of collection and it did not belong to an existing specimen. However, only pieces of oligochaetes with the anterior portion, showing the mouth opening, were mounted and identified; other pieces of oligochaetes were not counted. Invertebrates were identified to the following taxonomic levels:

- Bivalvia - genus
- Gastropoda - family or species
- Nematoda - nematodes
- mites - mites
- Oligochaeta - genus or species
- Polychaeta - species
- Turbellaria - turbellaria
- Hirudinoidea - species
- Diptera - genus, species group, or species
- Trichoptera - genus
- Ephemeroptera - genus or species.

Immature tubificid oligochaetes do not have well developed sexual structures, which are necessary for definitive identification of several species. Consequently, these individuals were separated into three groups: 1) immature tubificids without dorsal hair chaetae; 2) immature tubificids with dorsal hair chaetae; and 3) very immature tubificids lacking all chaetae. Although specimens in these three groups likely represent species with individuals already identified from the same replicate, these groups were treated as separate taxa and were included in taxa richness counts.

All midges and worms were mounted on slides using Hoyer's mounting medium. One midge was mounted per cover slip, and up to three cover slips were mounted per slide. Up to ten worms were mounted per cover slip, with one to two cover slips per slide. About 1,500 slides were prepared. An undergraduate biology student was trained by the Senior Taxonomist to assist in the identification of midges and worms. However, all identifications were made or verified by the

Senior Taxonomist. Data for each sample were recorded on separate data sheets and arranged in a three-ringed binder according to site and station.

2.3.3.3 Quality control

The sample tracking work sheets were used to record the steps through which each sample went in the sample processing and identification procedures. Quality control (QC) checks were performed on the picking procedure. One randomly chosen sample out of every ten samples was immediately repicked for accuracy; a total of 25 samples were repicked by the Senior Taxonomist

2.3.3.4 Calculations

The core sampler had an inner diameter of 1.62 inches (or 4.13 cm). Thus, the total surface area of bottom substrate collected per core was calculated as 13.4 cm^2. The data were converted to numbers of organisms per square meter by using the following conversion factors:

1 core per replicate = 747.4
2 cores per replicate = 373.7
3 cores per replicate = 249.1

The Ponar grab sampler was 6x6 inches, which was equivalent to 232.2 cm^2 of surface area of bottom substrate collected per grab. A conversion factor of 43.06 was used for Ponar samples.

CHAPTER 3

RESULTS

3.1 SITE INFORMATION

3.1.1 Sample Locations

Figure 2-1 shows the overall locations of the hotspot areas sampled in the Duluth/Superior Harbor. The Kimball's Bay area was included as a reference site. The precise location of the coring stations within the nine general areas sampled are shown in Figures 3-1 through 3-9. The geographical coordinates of these stations are provided in Table 3-1.

3.1.2 Site and Sediment Descriptions

3.1.2.1 Bay south of the DM&IR taconite storage facility

Five sites were sampled in the bay south of the DM&IR taconite storage facility (DMIR 1-5; Figure 3-1). A small MPCA vessel was used to sample the sites on August 23, 1994. Because all the sediments at these locations were a dark brown silty clay with a high concentration of taconite pellets, the gravity corer could not be used. Instead, a Ponar grab sampler was used to obtain the surface sediments. A single Ponar was used per benthos replicate (Table 3-2).

3.1.2.2 Bay east of Erie Pier

The small bay east of Erie Pier and southwest of the International Welding and Machinists site was sampled for benthos enumeration, toxicity testing, and surficial chemistry analysis (Table 3-2). Five sites, ERP 1-5, were visited in this area (Figure 3-2) on October 4, 1994. Three cores per replicate were used for benthos enumeration. Toxicity tests were conducted using surficial sediment from sites ERP 1, 2, and 3. The gravity corer obtained very short cores at this site (5-8 cm in depth). The physical descriptions of the sediments obtained from these sites are provided in Table 3-2. The sediments were quite variable in this bay.

3.1.2.3 Howard's Bay

Fifteen sites were sampled within Howard's Bay (HOB 1-15) (Figure 3-3). Eight of these sites were sampled for toxicity testing using a "worst-case" approach. Benthos and chemistry samples were taken for surficial sediments at all sites (Table 3-3). Two additional sediment sections, from the vibrocore, were submitted for chemical analyses (as described in Table 2-1).

The visual description of the Howard's Bay sediments is given in Table 3-3. Samples HOB 1, 2, 3, 5, 7, and 11 were located in the shipping lane within Howard's Bay, with site HOB 1 being closest to the mouth of the bay and site HOB 15 closest to the end of the bay (Figure 3-3). Sites HOB 4, 6, and 10 were located north of the Howard's Bay shipping channel, and south of the Main St. (Superior) peninsula.

Sites HOB 8 and 9 were just outside the entrance to active Dry Dock No. 2. These sites seemed very well-scoured. The substrate was extremely hard red clay (with a bit of grit overlying the clay at site HOB 9). Because this hardpan was nearly impossible to sample with the vibrocorer, deep cores were not taken at these two sites. The gravity corers were able to obtain only very short cores at these two sites (5 cm deep). Due to the great water depth at this location (7.0 m), it was not possible to manually push the core deeper into the sediment as was done at the MLH sites.

Sites HOB 12 and 13 were located just outside the entrance to Dry Dock No. 1 (also active). The gravity corers were able to penetrate a bit deeper into these sediments (10 cm); however, these sites were also well-scoured, with the hardpan located very close to the surface. Therefore, vibrocore samples were not collected at these two sites.

Sites HOB 14 and 15 were located at the terminus of the bay, past the boundary of the dredged channel. Site 15 was sampled as far to the end of the bay as the Mudpuppy could venture. The two sites were very different from one another. The surface sediment from HOB 14 was very similar to those sediments north of the shipping channel, consisting of a loose, flocculent sand/clay mixture atop clay. The deep core was very stiff red and brown clay to the bottom (0.45 m). The surface sediment from site HOB 15 was very similar: dark brown loose clay with gritty sand. In contrast, deep sediment from this site contained very heavy black oil, for the entire depth, from 0.15-1.2 m. An oil slick was apparent on the water surface while sampling.

3.1.2.4 Kimball's Bay

An area of Kimball's Bay, just west of Billings Park, was used as a reference site based on the results of the 1993 survey. Only surficial samples were obtained from these sites. Five sites were sampled (KMB 1-5) on October 4, 1994 (Figure 3-4). Sites KMB 1, 2, and 3 were located in the large, open area of Kimball's Bay, whereas sites KMB 4 and 5 were located in two smaller arms of the bay. Toxicity tests were conducted with sediment from sites KMB 4 and 5. Three gravity cores were collected per replicate for the benthos enumeration (Table 3-2).

Sediment descriptions of the sites are given in Table 3-2. Sediments from these sites were described, in general, as soft brown clay with or without the presence of an oxidized iron layer near the top of the gravity core.

3.1.2.5 Bays north and south of the M.L. Hibbard/DSD No. 2 plant

Ten sites were sampled from the bays. Samples for toxicity tests were collected at sites MLH 1-6 as a "worst-case" evaluation (Table 3-4). Sites MLH 1-4 were on the north side of the M. L. Hibbard/DSD No. 2 plant, and sites MLH 5-10 were in the bay south of the plant (Figure 3-5). A gravity corer was used to collect surficial sediments at most of the locations. However, at sites MLH 2, 3, and 6 (which had less penetrable gritty fly ash), the corer was modified by duct-taping it to a grappling hook in order to sample the appropriate layer (i.e., 0-15 cm). The sub-surface sediments were sampled with a Livingston corer to obtain the deepest layer possible. Chemical analyses were performed on two sections from each site: 0-15 cm and the deepest layer obtainable (Table 3-4).

3.1.2.6 Minnesota Slip

Five cores (MNS 1-5) were collected in Minnesota Slip, the northeastern-most slip in the Duluth/Superior Harbor, just inside the Duluth entry (Figure 3-6). Four core sections were collected and analyzed for sediment chemistry at each site. Three gravity cores per replicate were used for the benthos enumeration (Table 3-5).

Descriptions of the sediments obtained from Minnesota Slip are given in Table 3-5. Of all the areas sampled in this sediment assessment, the Minnesota Slip core sections showed the highest degree of oil contamination.

3.1.2.7 City of Superior WWTP

The outfall of Superior's WWTP is on a small peninsula, adjacent to the dredged Superior Front Channel. Two sites were sampled on the northwest side of the outfall, and eight in the bay to the southeast of the outfall and near Barker's Island (Figure 3-7). Toxicity test samples were collected at sites closest to the outfall location: STP 1, 3, 4, 6, and 7. The sampling protocol called for three sediment sections to be analyzed from these sites: 0-15 cm (collected with the gravity corer), as well as 15-30 cm and 30-45 cm (collected with the vibrocorer). A total of three vibrocorer nose cones were lost at sites STP 3 and STP 5; therefore, extreme care had to be taken not to penetrate the clay too deeply on subsequent sampling attempts.

Descriptions of the sediments sampled in this area are given in Table 3-6. Because of the difficulty involved with coring some of the sediments, it was decided to drop site STP 11, along the Superior Front Channel. In addition, site STP 10, which was in the deeper portion of the bay, was very sandy in the surficial sediment layer. Attempts to find softer sediment in this area were unsuccessful; therefore, it was decided not to vibrocore these sediments in order to prevent the potential loss of another nose cone. Site STP 9 could not be sampled due to the shallow water depth. Sites STP 6-8 were located in the center of the bay. Again, because of concerns about losing nose cones, the vibrocoring was limited to approximately the top 0.4 m to avoid the hard sand layer below.

From site STP 8, the water depth was not suitable for sampling until the area near site STP 10. The final site in this bay, STP 12, was quite different from the other sites. The surficial sediment was soft, loose brown clay, with a slight oil sheen. A deeper core was obtainable here: approximately 0.9 m. Each section in this core was contaminated with heavy, black oil which was mixed with either sand or clay. Because this was such an unusual site, 3 vibracore sections were taken from this core at 15-30 cm, 30-46 cm, and 76-91 cm. All of these samples from STP 12 were submitted for PAH analysis. The source of the oil was unknown. However, it is of note that this site was about 30 m from the outfall of a city creek. This area was not known to be contaminated (Scott Redman, WDNR, personal communication).

3.1.2.8 Slip C

Eight sites were sampled in Slip C on September 22, 1994 and October 3, 1994 (SUS 1-8). The cores were sampled sequentially from the furthest inward site (SUS 1) to near the mouth of the slip (SUS 8, Figure 3-8). Four sites (SUS 1, 3, 5 and 7) were sampled for toxicity testing, and all sites were sampled for surficial benthos enumeration and surficial chemical analysis. Because of the complex nature of the contamination found in this area in the 1993 survey, four sediment layers were sent for chemical analysis from each site (Table 2-1).

Visual descriptions of the sediments obtained from this slip are provided in Table 3-7. At site SUS 8, the closest to the mouth of the slip, only a single 10-cm surface sediment core was obtained after many attempts. It consisted of coarse sand. No vibrocoring was attempted at this site due to the hard sand substrate. A large amount of fibrous, woody material was found in the sediments south of the Georgia-Pacific Corp. Plant.

3.1.2.9 WLSSD and Miller and Coffee Creek Embayment

The bays southwest of WLSSD and south of the outfalls of Miller and Coffee Creeks were sampled during September 21-27, 1994. Twenty-three sites were visited within this embayment. However, core samples could be obtained at only 19 of the 23 planned sites (Figure 3-9). Due to heavy rip-rapping of logs, shallowly buried in sediments near the western edge of the embayment, samples from sites WLS 20-23 could not be collected.

Three sites (WLS 6, 9, and 11) were located in the formerly dredged 21st Avenue West shipping channel. The rest of the sites were located in the shallow portions of the bay; all sites were north of the main shipping channel, bounded by Rice's Point, the WLSSD facility, and the DM&IR taconite storage facility.

Surficial sediments were obtained for benthos enumeration and contaminant analysis at all 19 sites. Vibrocores were collected at each site for analysis of contaminants in the buried sediments. Table 2-1 indicates the analytes measured in each core section. Samples for toxicity testing were collected at 10 of the sites (Table 3-8): WLS 1, 2, 3, 4, 6, 8, 12, 13, 14, and 16. A "worst-case" approach was used in deciding which samples should be tested for toxicity. That is, locations expected to have the most highly-contaminated sediments in a given area (based on the 1993 survey and knowledge of potential contaminant sources) were tested for toxicity.

Descriptions of the sediment samples collected are provided in Table 3-8. In general, there was great uniformity within each site in terms of the sediment appearance of the surficial sediment samples collected with different coring devices for the benthos enumeration, toxicity tests, and chemical analysis. As detailed in Table 3-8, oil was present in many core sections, whereas coal chunks were present in a few core sections. Many sections also contained fibrous material and occasional wood chips.

3.2 CHEMICAL ANALYSES

Chemical results are presented in graphical and/or tabular format in the following sections. The analytical data is provided in electronic format in Appendix A. All chemical concentrations given in this section are reported on a dry weight basis. The potential sources of contaminants to the Duluth/Superior Harbor were described in the 1993 sediment survey report (Schubauer-Berigan and Crane, 1997) and will not be repeated here.

In order to interpret the chemical data, it is useful to compare the data to some kind of benchmark such as a criteria or guideline value. The U.S. EPA has developed draft sediment quality criteria for five nonionic organic compounds: acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene (U.S. EPA, 1994b). Additional sediment quality criteria will be developed by the EPA for nonionic organic compounds and for metals once the methodology has been approved. The Great Lakes States and EPA Regions will use the EPA's sediment criteria to assist in the ranking of contaminated sediment sites needing further assessment, to target hotspots within an area for remediation, and to serve as a partial basis for the development of State sediment quality standards. These criteria will also be used to assist in selecting methods for contaminated sediment remediation and for determining whether a contaminated site should be added or removed from its list of designated Areas of Concern (U.S. EPA, 1994b).

The State of Minnesota has not developed sediment quality criteria, or guidelines, for contaminants. The MPCA has secured a grant from GLNPO (for FY98-99) to develop site-specific sediment quality guidelines for the St. Louis River AOC. These biologically-based guidelines will utilize matching sediment chemistry and toxicity data. Where data gaps exist, regional and national data will be used to develop guideline values.

In the meantime, other jurisdictions from Canada, the Netherlands, and the United States (e.g., New York) have developed sediment quality values (Crane et al., 1993) which may be useful to compare to the results of this investigation. The Ontario Ministry of Environment and Energy (OMOEE) guidelines may be the most useful to compare to the results of this survey, because their guidelines are based on freshwater toxicity data. Many other jurisdictions incorporate marine data into their derivation of guidelines or criteria. The OMOEE currently uses a three-tiered approach in applying sediment quality guidelines (Persaud et al., 1993):

- **No Effect Level (NEL):** the level at which contaminants in sediments do not present a threat to water quality, biota, wildlife, and human health. This is the level at which no biomagnification through the food chain is expected.

- **Lowest Effect Level (LEL):** the level of sediment contamination that can be tolerated by the majority of benthic organisms, and at which actual ecotoxic effects become apparent.

- **Severe Effect Level (SEL):** the level at which pronounced disturbance of the sediment dwelling community can be expected. This is the concentration of a compound that would be detrimental to the majority of the benthic species in the sediment.

In some cases, background levels of contaminants may exceed the LEL value. In this case, the background level should be used in place of the LEL value. For northeastern Minnesota, there is insufficient data for most contaminants to determine background concentrations. The OMOEE guidelines are only used in this report as general benchmark values since they have no regulatory impact in Minnesota.

3.2.1 Particle Size

All of the samples were analyzed for particle size distribution. A detailed analysis of the following size ranges was performed:

- fine clay: <0.08 μm
- medium clay: 0.08-0.2 μm
- coarse clay: 0.2-2 μm
- fine silt: 2-5 μm
- medium silt: 5-20 μm
- coarse silt: 20-53 μm
- sand and gravel: >53 μm.

None of the samples contained any sediment in the fine clay and medium clay fractions. The size distributions were further simplified into the following ranges (Table 3-9):

- clay: 0-2 μm
- silt: 2-53 μm
- sand and gravel: >53 μm.

The sand and gravel (>53 μm) and silt (2-53 μm) fractions were the most dominant fractions. Red clay (0-2 μm) exceeded 45% at some of the Howard's Bay sites (especially HOB 11). The surficial sediments from KMB 4 and KMB 5 were over 25% clay. Most of the depth profiles at the other sites had a clay content less than 20%.

Some of the sandiest sediments were found at Erie Pier (especially ERP 2-5) and Slip C (especially SUS 5-7 and the deepest core sections of SUS 1, SUS 2, and SUS 4). Some of the "high" sand and gravel values for the inner SUS sites may actually be due to wood chunks and wood fibers in the sediments resulting from operations at the nearby Georgia-Pacific plant. This plant produces compressed wood products. High sand and gravel concentrations exceeding 90% were also found in selected core sections of the following sites: HOB 6, MLH 6, MLH 8, MNS 4, MNS 5, and WLS 4.

The highest silt content (i.e., 66.7%) was measured in the 189-204 cm core segment of WLS 1. This site was located closest to the Miller and Coffee Creek outfalls. The next highest silt measurement (i.e., 66.3%) was found in the 30-45 cm segment of STP 4. This site was located east of the city of Superior WWTP outfall. The highest surficial silt content of 64.3% was measured in the 0-20 cm core segment of WLS 9. This site was located in the 21st Avenue West Channel which is no longer dredged.

The WLS and STP sites generally had the highest silt concentrations. This appears to be predominately due to the deposition of silt particles from stormwater and effluent discharges. The KMB and DMIR areas also had several surficial sites exceeding 45% silt; most of these sites are not dredged.

3.2.2 Total Organic Carbon

All of the samples were analyzed for TOC (Table 3-10). The lowest TOC value of 0.18% was measured in the 60-76 cm segment of MLH 8; this sample was composed of coarse brown sand. The highest TOC value of 27% was noted at two WLS sites: WLS 5 (30-45 cm), which contained oil and coal chunks, and WLS 8 (90-105 cm) which contained wood fiber. Other high TOC values were recorded in sediments containing either oil, fly ash, coal, or wood detritus. Most of the surficial samples were below 5% TOC.

3.2.3 Ammonia

Surficial ammonia was measured at five of the hotspot areas, as well as Kimball's Bay (Table 3-11). In addition, ammonia was measured in the bottom core segment of the WLS sites (Table 3-11). The lowest ammonia concentration of 3.3 mg/kg was measured in the upper 5 cm of ERP 5. The highest ammonia concentration of 219 mg/kg was measured in the 0-21 cm segment of WLS 11; this site was located in the old 21st Ave. West Channel. The ammonia concentrations were compared to the Ontario Open Water Disposal guidelines of 100 mg/kg ammonia. Two sites in Kimball's Bay, two sites in Minnesota Slip, six surficial sites in the WLSSD/Coffee and Miller Creek embayment, and seven deep sites of this embayment exceeded the Ontario guidelines.

3.2.4 Total Arsenic and Lead

Total arsenic and lead were measured at all of the depth profiles for the Howard's Bay sites (Table 3-12). All but five samples exceeded the OMOEE LEL value of 6 mg/kg for arsenic. The 15-30 cm segment of HOB 14 exceeded the OMOEE SEL value of 33 mg/kg arsenic. All but four samples exceeded the OMOEE LEL value of 31 mg/kg lead. Three sites exceeded the OMOEE SEL value of 250 mg/kg lead. These sites included the: 5-20 cm segment of HOB 1 (1,500 mg/kg), 30-45 cm segment of HOB 4 (1,350 mg/kg), and 0-10 cm segment of HOB 13 (269 mg/kg). HOB 1 was located in the navigation channel west of the Highway 53 bridge, HOB 4 was located northeast of the shipping channel, and HOB 13 was located at the entrance of Dry Dock No. 1 (Figure 3-3). Figure 3-10 shows the depth profile of lead at each of the HOB sites; in some cases, only a surficial sample could be collected due to the hard sand substrate.

3.2.5 AVS and SEM

AVS and SEM were measured at Kimball's Bay and four of the hotspot areas (i.e., DMIR, ERP, HOB, and MLH sites). AVS results are given in Table 3-13, whereas the SEM results for cadmium, copper, nickel, lead, and zinc are given in Table 3-14. The individual SEM values were normalized for AVS and summed together in Table 3-15.

SEM/AVS ratios greater than 1.0 indicate bioavailability of the divalent metal, and hence a greater chance of toxicity to benthic biota (Ankley et al., 1994). The SEM/AVS depth profiles for three Howard's Bay sites are shown in Figure 3-11. The SEM/AVS ratios were much greater in the deeper sections of the HOB sites than in the surficial sections. The highest SEM/AVS ratio of 46 was recorded in the 30-45 cm section of HOB 7. Unless this section was re-exposed to the surface, it presents a low risk to biota since they would not be exposed to the deeper sediments. For the surficial SEM/AVS ratios, the highest value of 17 was recorded for the 0-5 cm section of HOB 8; copper and zinc contributed the most to this exceedance. HOB 8 was located at the entrance of Dry Dock No. 2.

Thirty-eight percent of the surficial sites exceeded a SEM/AVS ratio of 1.0, including all four DMIR sites. Erie Pier and Kimball's Bay had the lowest SEM/AVS ratios, except for one site at each location which exceeded 1.0.

The SEM lead and total lead values for Howard's Bay are compared to each other in Table 3-16. For the two sites grossly contaminated with total lead [i.e., HOB 1 (5-20 cm) and HOB 4 (30-45 cm)], the corresponding SEM results were much lower. This indicated that much of the lead at these core sections was not bioavailable.

3.2.6 Mercury

Mercury was measured at most of the sample sites, except for the ERP and DMIR sites. Most of the samples exceeded the OMOEE LEL of 0.2 mg/kg (Table 3-17). Mercury concentrations ranged from nondetectable at a few HOB sites to 3.9 mg/kg in the 30-45 cm section of WLS 12 (Figure 3-12). This later value exceeded the OMOEE SEL value of 2.0 mg/kg mercury. The 15-30 cm section of WLS 13 was also high in mercury with a concentration of 2.9 mg/kg (Figure 3-12).

The depth profile of mercury at Slip C is shown in Figure 3-13. For the most inland samples, mercury peaked in the 30-45 cm section. This section was characterized by a lot of woody, fibrous material with oil interspersed in it. Although the inland sites were located near the Georgia-Pacific plant, other potential historical sources of contamination would need to be evaluated before determining the source of this contamination.

The Howard's Bay mercury samples were not analyzed in a timely manner. The samples were stored in whirlpak bags for approximately two years before analysis. As a result of this long storage period, some of the environmental replicates had unacceptable QC for precision (Table 3-17).

The deepest core sections of the SUS and WLS sites were generally low in mercury (i.e., <0.2 mg/kg mercury). Thus, anthropogenic inputs from point and nonpoint sources have contributed to the mercury load in the more recently deposited Duluth/Superior Harbor sediments.

3.2.7 Dioxins/Furans

The upper two core sections of the WLS samples, in addition to the surficial KMB samples, were analyzed for 2,3,7,8-TCDD (dioxin) and 2,3,7,8-TCDF (furan). The analysis of the WLS samples proved difficult due to an abnormal sediment matrix. Some WLS samples contained cresosote-like chunks that interfered with the sample extraction.

As shown in Table 3-18, some samples had 0% surrogate recovery. Since there was not enough sediment left over for the 0-15 cm sections of WLS 1, 2, 6, and 8 to be rerun, no results were available for these samples. Acceptable TCDD results were obtained for 10 WLS samples, whereas 17 WLS samples had acceptable TCDF results. For the WLS samples, TCDD ranged from 3.4-22 pg/g and TCDF ranged from 0.7-37 pg/g. Neither TCDD or TCDF were detected at any of the KMB sites.

3.2.8 PAHs

3.2.8.1 PAH fluorescence screen

The PAH fluorescence screen was used as an inexpensive, semi-quantitative technique to evaluate a large number of samples for PAH contamination. Samples from the KMB, MLH, MNS, SUS, and WLS sites were measured using this technique (Table 3-19). Qualitatively, the screening method did not appear to correlate well with the corresponding quantitative PAH results (Table 3-20). In most cases, the screening method grossly over-estimated the total PAH concentrations as measured by GC/MS by one to two orders of magnitude. This difference may be partly due to differences in the number of PAH compounds measured by each technique. Sixteen PAH compounds were measured by the GC/MS method, whereas compounds containing aromatic rings, such as PAHs, were measured in the fluorescence screen. Thus, other compounds besides PAHs may have been measured in the PAH screen.

Some PAH fluorescence results underestimated the GC/MS results by one to two orders of magnitude at the MNS, SUS, and WLS sites. No comparisons could be made for the STP samples as quantitative results were only obtained on one core; the screening method was not run on the STP samples.

Figure 3-14 contains the depth profile of screening PAHs measured in Slip C. In comparison, GC/MS-determined PAHs for selected core sections of this boat slip are shown in Figure 3-15.

Due to the variability in the screening PAH results, it was not possible to estimate the GC/MS PAHs, with a high degree of confidence, for the missing core sections.

For this study, the screening PAH data were of limited usefulness for designating sites that warranted quantitative PAH analysis. Physical observations about the sediment core sections provided a good (and less expensive) indicator of PAH contamination. That is, samples that appeared oily or contained fly ash, coal tar, coal, or wood product appeared to have the greatest PAH contamination in this study. Thus, for the Duluth/Superior Harbor, physical observations about the samples may provide a quick way of pre-selecting samples for quantitative PAH analysis during field collection.

3.2.8.2 PAHs by GC/MS

Sixteen PAH compounds were quantified, by GC/MS, on selected samples from the KMB, MLH, MNS, STP, SUS, and WLS sites (Table 3-20). The PAH results were normalized for TOC in Table 3-21.

The data in Table 3-20 were compared to the OMOEE LEL values for available PAH compounds and total PAHs. For values less than the detection limit, one-half the detection limit was used to calculate total PAHs. Some of the results presented in Tables 3-20 and 3-21 were merged from two separate sample runs. This was done because some PAH compounds exceeded the upper calibration limit when the samples were run on the GC/MS. In this case, the sample was diluted and rerun to bring the values within the calibration limit. The combined data results, then, represent all the acceptable values from the first run plus the second run dilution values for compounds that exceeded the calibration limits in the first run. Some results were only presented by the analytical laboratory at a secondary dilution factor; these results are flagged in Tables 3-20 and 3-21.

Most of the surficial sediments had total PAH concentrations that exceeded the OMOEE LEL value of 4,000 µg/kg, except at Kimball's Bay (mean = 2,000 g/kg) and a few other sites. The OMOEE SEL site-specific organic carbon normalized total PAH value was only exceeded in the 15-30 cm segment of MNS 4. As indicated in the 1993 sediment survey of the harbor, PAH contamination appears to be widespread in the harbor (Schubauer-Berigan and Crane, 1997). The highest surficial PAH contamination occurred at Minnesota Slip (Figure 3-16). The PAH concentrations at various depth intervals were also high at this site. Slip C (SUS sites) also had widespread PAH contamination.

PAHs were measured in the bottom core segment of the 19 WLS sites. Only one of these samples, WLS 9, exceeded the OMOEE LEL value. This site was located in the 21st Ave. West Channel which was used as a disposal site for dredged material shortly before the Erie Pier confined disposal facility was built (Al Klein, Army Corps of Engineers, personal communication, September 11, 1997). Thus, the sediment profile for WLS 9 was not representative of the rest of the WLS sites.

The proportion of PAH compounds present at each site was not examined. This procedure, in addition to the use of multivariate statistics, could be used to determine sources of PAHs. There are likely to be several historical and current sources of PAHs to the harbor resulting from the incomplete combustion of coal and wood, as well as from coal tar sources, coking operations, coal gasification plants, nonpoint runoff, and atmospheric transport and deposition of PAH compounds.

3.2.9 PCBs

3.2.9.1 Total PCBs

Congener-specific PCBs were measured at Kimball's Bay and four hotspot areas (MNS, STP, SUS, and WLS sites). The congeners were summed to yield total PCB concentrations (Table 3-22). Nearly all of the core depths sampled exceeded the OMOEE No Effect Level (NEL) of 10 ng/g PCBs. The OMOEE LEL value of 70 ng/g PCBs was exceeded at most of the sites, except Kimball's Bay and some of the deeper core sections of the hotspot sites. The OMOEE SEL value of 530 μg/g organic carbon was not exceeded at any of the sites.

The highest PCB concentrations were located in the 30-45 cm core segment of WLS 12 (1,270 ng/g) and WLS 1 (1,220 ng/g). WLS 12 was located south of the WLSSD outfall, whereas WLS 1 was the closest site to the Miller and Coffee Creek outlets. PCBs were also high in the 15-30 cm segment of SUS 5 (1,140 ng/g). The depth profile of PCBs for the SUS sites are given in Figure 3-17. The highest peak of normalized PCBs occurred in the 15-30 cm section of SUS 5. This sediment section was very oily when it was collected.

3.2.9.2 Congener PCBs

A subset of seven PCB congeners (Table 3-23) were selected for presentation in Table 3-24. The full distribution of PCB congeners are available from the MPCA upon request. Congener numbers 101, 128, and 180 were selected due to their high priority for potential environmental importance based on potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues (McFarland and Clarke, 1989). Congener numbers 18, 52, and 201 were included on McFarland and Clarke's (1989) secondary list of important congeners. Congener number 6 was selected to provide a representative dichlorobiphenyl measured in the samples.

The distribution of congeners may provide an indication of different sources of PCBs to the watershed. However, it was beyond the scope of this project to evaluate the data in that way. Congener numbers 52 and 101 generally had the highest concentrations relative to the rest of the congener subgroup. PCB congeners were detected even in the deepest core sections of the WLS sites down to 250 cm (i.e., at site WLS 6). Site WLS 6 was located in the 21st. Ave. West Channel; this channel received dredged material for a few years during the 1970s. Thus, a deep layer of sediments has been deposited at this site since PCBs came into production this century.

3.3 TOXICITY TESTS

The 10-day toxicity tests were conducted on six batches of samples, all of which were run within two months of sample collection. The two month holding time was acceptable for this study. Detailed information on the sample collection and handling, methods, water quality and survival results, data analysis, and *H. azteca* reference toxicant test results are provided in MPCA laboratory reports given in Appendix B. In general, the pH ranges of all the toxicity tests were acceptable. However, dissolved oxygen concentrations occasionally fell below 40% saturation in the *C. tentans* tests. Temperature was slightly less than the recommended range of 23 ± 1°C (U.S. EPA, 1994a) for most tests (i.e., down to 19.5°C).

In order for the test to pass, the mean control survival for *H. azteca* had to be greater or equal to 80%. For *C. tentans*, a mean control survival of 70% or greater was required for the test to pass. Survival data from acceptable tests were analyzed statistically using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. All survival data were expressed as a proportion and were transformed using an arc sine-square root transformation prior to analysis. The Shapiro-Wilk's test for normality and Bartlett's test for homogeneity of variance were run on the transformed data. Next, an Analysis of Variance (ANOVA) was conducted. Next, the data were analyzed statistically using either a one-tailed Dunnett's test ($p = 0.05$) or nonparametric statistical analysis, as needed. A sample was considered toxic when mean percent survival was significantly lower than mean control survival.

3.3.1 Acute Toxicity to *Hyalella azteca*

Table 3-25 shows the mean percent survival of *H. azteca* resulting from the 44 toxicity tests. One batch of six tests, shaded in Table 3-25, failed due to barely unacceptable control survival (i.e., 78%). For this batch of tests, two of the samples had 80% survival, and the corresponding reference toxicant controls had acceptable survival (i.e., 93%). Therefore, the *H. azteca* culture appeared to be healthy. Although the results were not analyzed statistically, due to control failure, the mean percent survival in SUS 7 (i.e., 45%) and STP 6 (i.e., 50%) appeared to be highly depressed relative to the control.

Of the tests that had acceptable control survival, five samples had significantly less survival than the corresponding controls: DMIR 1, ERP 2, HOB 12, HOB 13, and MLH 4. Of these sites, only DMIR 1 had significant mortality in the *C. tentans* test as well. The specific cause of toxicity could not be determined.

In Table 3-26, the test survival was divided by the corresponding control survival to yield a normalized survival value. This procedure allowed non-contaminant effects to be separated from contaminant effects. Because sample survival was examined relative to the control survival, it is possible to have percent survival numbers greater than 100%. The U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) considers sediments with survival less than 80% to be toxic, and less than 60% to be very toxic (Strobel et al., 1995). Of the statistically significant samples designated in Table 3-26, all five samples had normalized survival values less than 80%;

one sample, HOB 13, was very toxic with a normalized survival of 59%. Five other samples, including two samples that barely failed the toxicity test (e.g., STP 6 and SUS 7), also had normalized survival less than 80%. Samples ERP 1 (73%), HOB 11 (77%), and WLS 3 (78%) appeared to have toxicity due to contamination. Qualitatively, STP 6 (64%) and SUS 7 (58%) appeared to be toxic and very toxic, respectively.

3.3.2 Acute Toxicity to *Chironomus tentans*

The survival of *C. tentans* in the 10-day sediment toxicity tests is given in Table 3-25. Two batches of tests failed due to unacceptable control survival (i.e., <70%). The test batch including ERP 3, KMB 4, KMB 5, STP 6, STP 7, and SUS 7 barely failed with a corresponding control survival of 68%. The test batch including HOB 7, HOB 8, MNS 1, MNS 3, STP 1, STP 4, SUS 5, WLS 12, WLS 13, WLS 14, and WLS 16 had a larger control failure of 52% mean control survival. Qualitatively, some interpretation can be provided for the previous batch. The later batch had too much control mortality to qualitatively interpret the test results.

Of the samples that had acceptable control survival, three samples (DMIR 1, SUS 3, and WLS 1) had significantly less survival than the corresponding controls. The specific cause of toxicity could not be determined. All three of these samples had normalized survival less than 80%; SUS 3 was very toxic with a normalized survival less than 60% (Table 3-26).

Of the other samples that had acceptable control survival, STP 3 and SUS 1 appeared to have some toxicity due to contamination. Of the samples which barely failed the toxicity test, KMB 4 appeared to be toxic and SUS 7 was extremely toxic. SUS 7 was the only sample that had 0% mean survival.

3.3.3 Chronic Toxicity to *Chironomus tentans*

Growth (weight) was measured at the end of the *C. tentans* test to assess chronic effects. Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Due to this quality assurance problem, the growth data could not be analyzed statistically.

3.4 BENTHOLOGICAL ASSESSMENTS

3.4.1 Sampling Design

A total of 241 samples were collected from nine areas within the Duluth/Superior Harbor during August to October 1994. At each site, four to twenty stations were designated, and three replicate samples were collected with a gravity core sampler. Exceptions to this sampling design were as follows:

- the DMIR sites were sampled with a Ponar grab sampler (6 x 6 inches)
- site WLS 20 was not sampled
- sites STP 9 and STP 11 were not sampled
- ERP 4 was sampled, but the samples were misplaced. These samples were discovered too late to have them enumerated.
- only one replicate was taken at site SUS 8.

3.4.2 Ecology and Feeding Habits of Abundant Benthic Organisms

Although the macroinvertebrate fauna varied throughout the harbor, some organisms were commonly found at most of the sites. Section 3.4.3 discusses the mean total abundance and taxa richness values for each hotspot area and Kimball's Bay. This section provides a brief summary of the most abundant organisms found, including their ecology and feeding requirements [as described in Pennak (1978)]. The most abundant organisms in the harbor have adapted to living in a slow moving water environment and have developed strategies to tolerate low dissolved oxygen conditions. Some of these organisms are also pollutant tolerant, thus giving them a competitive advantage for living in contaminated sediments.

3.4.2.1 Oligochaetes: Naididae and Tubificidae

The Naididae and Tubificidae are oligochaetes (i.e., aquatic earthworms). They are commonly found in the mud and debris substrate of streams and lakes, especially in stagnant areas. They are sometimes abundant in masses of filamentous algae. These organisms ingest substrate down to 2-3 cm below the surface, digesting the organic component as it passes through their alimentary canal. Food may consist of filamentous algae, diatoms, or miscellaneous plant and animal detritus.

Tubificids, especially *Tubifex tubifex*, are concentrated in areas contaminated with sewage. This species is usually considered an indicator of organic pollution, especially where the water is 10-60% saturated with oxygen. Most tubificids build tubes and project the posterior end of their body in the water to circulate it and make more oxygen available to the body surface (Figure 3-16). This movement allows them to thrive in low concentrations of dissolved oxygen. Many species are able to withstand the complete absence of oxygen for extended periods of time. Tubificid oligochaetes were abundant at all of the areas sampled in this survey.

3.4.2.2 Polychaetes: *Manayunkia speciosa*

Manayunkia speciosa has some of the same habitat and food preferences as the oligochaetes (Figure 3-16). *M. speciosa* is widely distributed in the Great Lakes region. It is 3-5 mm long and inhabits a tube built of either mud or sand and mucus. This species was abundant at certain stations of Kimball's Bay, Minnesota Slip, WLSSD embayment, and the M.L. Hibbard/DSD No. 2 and Grassy Point areas.

3.4.2.3 Phantom midges: Chaoborus

Chaoborus are in the order Diptera. The larvae are abundant everywhere in large ponds and lakes. Chaoborus migrate daily, being confined to the bottom waters and mud during the day and migrating to the surface waters at night. Chaoborus are predatory and catch small Crustacea and insect larvae. They are able to extract oxygen from the water at low concentrations through the use of a pair of pigmented air sacs in the thorax and another pair in the posterior end of the abdomen (Figure 3-16). Chaoborus were abundant at some stations of Howard's Bay and Kimball's Bay.

3.4.2.4 True midges: Chironomus

Chironomid larvae (e.g., blood worms) occur everywhere in aquatic vegetation and on the bottoms of all types of sluggish, fresh water bodies (Figure 3-16). They are mostly herbivorous and feed on algae, higher aquatic plants, and organic detritus. They build flimsy tubes of organic detritus, algae, and/or small sand grains and silt. Most of their food comes from plankton derived from the outside water and caught on temporary nets extending across the diameter of the tube.

Chironomid larvae are an important food item for young and adult fishes. Chironomids were commonly found in Kimball's Bay, the DM&IR site, Erie Pier, Howard's Bay, and Slip C. They were noticeably absent from Minnesota Slip.

3.4.3 Site Assessments

The following subsections provide mean total abundance and taxa richness values for each of the sites included in this study. The reference site at Kimball's Bay was intended to be used as an unimpacted site by which the other site data could be compared to. However, Kimball's Bay was not an appropriate reference site due to the low abundance and richness of organisms. Thus, there was no benchmark by which to classify the benthic community as being healthy or impacted to some degree. In general, most of the sites had low species richness and included taxa that were tolerant of moderate perturbations. Oligochaetes and chironomids were the dominant organisms. Similarly, a benthic study of three other Great Lakes AOCs (Buffalo River, NY; Indiana Harbor, IN; Saginaw River, MI) showed that oligochaetes and chironomids comprised over 90% of the benthic invertebrate numbers collected from depositional areas (Canfield et al., 1996).

3.4.3.1 DMIR sites

Except for DMIR 4, this area was characterized by very low mean total abundance (215-1,120 organisms/m^2) and taxa richness values (3 to 7) (Table 3-27). Tubificids dominated the fauna at these sites, comprising 73-82% of the fauna (Table 3-28). DMIR 4 was exceptional by having a mean total abundance of 2,985 organisms/m^2 and a richness value of 17; one replicate had a richness value of 23, which was the highest recorded richness value for the entire study. Eight taxa of chironomids, 6 taxa of other insects, 9 taxa of tubificids, and 4 other taxa were present amongst all of the sites (Appendix C).

3.4.3.2 ERP sites

Total mean abundance values were 4,900 to 14,283 organisms/m^2 and taxa richness values were 7 to 17 (Table 3-27). Site ERP 3 had the greatest values for each metric, whereas site ERP 5 had the lowest values. Chironomids, tubificids, and naidid oligochaetes dominated the fauna at these sites (Table 3-29). Chironomids were especially diverse, with 8 to 11 taxa collected at sites ERP 1-3; only 4 taxa were collected at ERP 5 (Appendix C). The greatest values of chironomid abundance and richness for all areas sampled during this study were found at ERP 3, with mean values of 3,654 larvae/m^2 and 11 taxa. Oligochaetes were also diverse at ERP 2, with 7 taxa present; naidid oligochaetes were absent at ERP 1 and very few were present at ERP 5. ERP 4 was not sampled.

3.4.3.3 HOB sites

Mean total abundance values for HOB 1-7 and HOB 10-15 ranged from 2,740 to 15,114 organisms/m^2 with mean taxa richness values of 6 to 15 (Table 3-27). Tubificids and chironomids comprised the majority of the fauna (35-73%), with *Pisidium* ranging from 2-27% and *Chaoborus* 0-24% (Table 3-30). HOB 8 and 9 appeared to be severely impacted, with a mean total abundance value of 249 organisms/m^2 and a mean taxa richness value of 1 for both stations. These sites were located outside the entrance to active Dry Dock No. 2, and they appeared to be well-scoured. The substrate was extremely hard red clay which was difficult to sample. Thus, physical factors may have had a limiting effect on the biota at HOB 8 and 9. The types of taxa observed at the HOB sites are given in Appendix C.

3.4.3.4 KMB sites

Kimball's Bay was chosen as the reference site. However, mean values of total abundance and taxa richness were low, with total organisms averaging 1,578 to 4,734 organisms/m^2 and richness values averaging between 3 to 8 at the five sites (Table 3-27). KMB 3 had the greatest abundance, with chironomid midges, tubificid oligochaetes, and the polychaete *Manayunkia speciosa* each comprising 25-32% of the faunal composition (Table 3-31). However, the chironomids and tubificids had low diversity of only 3 to 4 species at this site (Appendix C). The most abundant taxon was the phantom midge *Chaoborus* spp. at sites KMB 4 and 5, ranging from 498 to 3,986 larvae/m^2 and comprising 66-73% of the fauna (Table 3-31). Since, *Chaoborus* migrate vertically on a diurnal basis, the abundance of this organism varies daily.

It appears that Kimball's Bay was not suitable as a reference site. The macroinvertebrate fauna in the bay was low in abundance and diversity. This may be caused by unsuitable bottom substrates, or possibly low dissolved oxygen (DO) levels. The bay does not appear to have a substantial inlet feeder stream and it may be sheltered from the main flow of the St. Louis River. Thus, the DO levels may be a limiting factor. The most abundant benthic organisms in Kimball's Bay were tolerant of low DO levels.

3.4.3.5 MLH sites

Mean total abundance values for the 10 MLH sites ranged from 2,491 to 10,214 organisms/m^2; mean taxa richness values were low, ranging from 2 to 8 (Table 3-27). Tubificids were the dominant group at sites MLH 1-3 and MLH 10, comprising 42-69% of the fauna (Table 3-32). *Manayunkia speciosa* accounted for 33-79% of the fauna at sites MLH 4-9 (Table 3-32). The types of taxa observed at the MLH sites are given in Appendix C.

3.4.3.6 MNS sites

Minnesota Slip was dominated by oligochaetes. Tubificids had very high mean abundance values of 9,218 to 50,656 individuals/m^2, which comprised 59-89% of the fauna (Table 3-33). Naidid oligochaetes were also relatively abundant. Mean abundance values for total oligochaetes were 10,131 to 53,231 individuals/m^2 (Appendix C), which was the highest mean abundance value recorded for oligochaetes for the entire study. These two groups comprised 64-93% of the fauna and had taxa richness values ranging from 5 to 12 in the replicates. The clam *Pisidium* was relatively abundant at all stations with mean abundance values ranging from 1,163 to 2,907 clams/m^2. Nematodes were abundant at sites MNS 3 and 4, and *Manayunkia speciosa* was found at site MNS 4 in large numbers. The insects, especially chironomids, were nearly absent. MNS 2 had the highest mean value for total abundance recorded for this study, with 57,051 organisms/m^2 (Table 3-27). Overall, all stations recorded high mean total abundance values.

3.4.3.7 STP sites

Mean total abundance values ranged from 623 to 15,695 organisms/m^2, and mean taxa richness values ranged from 2 to 13 (Table 3-27). Site STP 8 had low total abundance and richness values. The fauna at all the STP sites was dominated by tubificids (21-61%); naidids were abundant at site STP 3 (41%) (Table 3-34). The types of taxa observed at the STP sites are given in Appendix C.

3.4.3.8 SUS sites

Oligochaetes were the dominant group at sites SUS 1-6, comprising 70-90% of the fauna, with tubificids making up 62-85% (Table 3-35). Chironomids accounted for 53% of the fauna at site 7. Mean total abundance values were relatively high at sites SUS 1-5 and SUS 7, with a range of 5,605-45,839 organisms/m^2 (Table 3-27). Mean taxa richness values ranged from 7 to 13 (Table 3-27). Site SUS 6 had lower mean values of 2,118 organisms/m^2 and a richness of 3; tubificids were absent at this site. Replicates B and C were not taken at site SUS 8 due to the sandy sediments. The types of taxa observed at the SUS sites are given in Appendix C.

3.4.3.9 WLS sites

Mean total abundance values ranged from 1,121 to 38,116 organisms/m^2, and mean taxa richness values ranged from 2 to 15 at the nineteen WLS sites that were sampled (Table 3-27). Tubificid oligochaetes were the dominant group, comprising 28-78% of the fauna. When tubificids were less than 50% of the fauna, *Manayunkia speciosa* accounted for 17-57% of the fauna (Table 3-36). *Pisidium* was relatively common, making up 9-26% of the fauna at sites WLS 1-11. The types of taxa observed at the WLS sites are given in Appendix C.

3.4.4 Chironomid Deformities

Deformities in the menta of chironomid larvae were recorded. *Chironomus* and *Procladius* were the only taxa that showed larval deformities (Table 3-37). Since the sample size was small, the results should be viewed as preliminary information. Chironomid larval deformities have been studied more intensely in a similarly contaminated AOC, the Buffalo River, NY. The genus *Chironomus* frequently displayed mentum abnormalities in the Buffalo River, whereas the genus *Procladius* appeared to either be more tolerant of industrial pollution, or else responded to a different suite of contaminants than did *Chironomus* (Diggins and Stewart, 1993). *Chironomus* generally display 0-3% abnormal menta at non-industrial sites (Diggins and Stewart, 1993).

3.4.5 Quality Assurance/Quality Control

The overall average picking efficiency was 92.4% (i.e. 7.6% of all organisms were missed during the first pick). Eleven of the 25 QC samples failed the 10% picking error level. However, ten of these samples were represented by very low numbers of total organisms (approximately 26); missing only a few specimens can artificially increase the picking error percentage, but have negligible impact on data interpretation. The remaining sample had a picking error of 16% with a total organism count of 275. The person who picked this sample failed to recognize 38 polychaetes that were hidden inside of their debris tunnels. This problem was immediately corrected and no further problems occurred. A picking efficiency of 96.9% (i.e., 3.1% picking error) is the result of the QA checks if the eleven samples just mentioned were disregarded. In summary, the QC checks for the picking efficiency procedure passed LSRI's internal error levels.

CHAPTER 4

SEDIMENT QUALITY TRIAD APPROACH

4.1 BACKGROUND

The Sediment Quality Triad (Triad) is an effects-based approach that can be used to describe sediment quality. With this approach, data from synoptic chemical and physical analyses, whole-sediment toxicity tests, and benthic community surveys are integrated to yield information on the range of clean to degraded sites in an area. Thus, a weight-of-evidence approach is used to develop an overall characterization of sediment quality. The Triad approach has been used successfully at other sites to:

- prioritize areas for remedial actions
- determine size of contaminated areas
- verify quality of reference areas
- determine contaminant concentrations always associated with effects
- describe ecological relationships between sediment properties and biota at risk (Chapman, 1992).

The three components of the Triad approach provide complementary data. However, no single component of the Triad can be used to predict the measurements of the other components (Chapman, 1992). The following assumptions apply to this approach:

- The Triad approach allows for: 1) interactions between contaminants in complex sediment mixtures (e.g., additivity, antagonism, synergism); 2) actions of unidentified toxic chemicals; and 3) effects of environmental factors that influence biological responses (including toxicant concentrations).
- Selected chemical contaminant concentrations are appropriate indicators of overall chemical contamination.
- Bioassay results and values of selected benthic community structure variables are appropriate indicators of biological effects (Chapman, 1992).

Triad data can be evaluated using several procedures, including ratio-to-reference (RTR) values and non-RTR methods (e.g., ranking and multidimensional scaling). With the RTR approach, all site data is normalized to reference site values by converting them to RTR values (Chapman, 1990). Thus, the values of specific variables (e.g., normalized concentrations of a particular contaminant, percent mortality in a particular bioassay, number of taxa) are divided by the corresponding reference values. The reference site may be a single station or an area containing several stations for which data are averaged. Mean indices of contamination, toxicity, and benthic community structure can be developed and plotted on triaxial plots (Chapman, 1992). The RTR approach has the following shortcomings:

- substantial loss of information during the conversion of multivariate data into single proportional indices
- loss of any spatial relational information
- inability to statistically assess significance of spatial impacts
- requirement of an appropriate reference station.

Ranking and multi-dimensional scaling methods reduce some of the problems associated with the RTR approach. Kreis (1988 as cited in Canfield et al., 1994) has developed procedures to rank toxicity, benthos, and chemistry data. Simple ranking can also be done by ranking the sites relative to each other for each endpoint (Table 4-1). The average of these rankings across endpoints orders the sites from impacted to clean sites, relative to each other. Either equal weightings can be given to each endpoint or a weighting system may be applied. Sites with very low and very high average rankings have the greatest degree of concordance among endpoints. Sites with intermediate average rankings could either have intermediate performance for all endpoints, or high performance for some endpoints and low for others, averaging out to intermediate.

Simple ranking can be used to combine information across endpoints with different scales. However, it loses the magnitude of the differences between sites by ranking the data. For example, sediment toxicity results of 0%, 40%, and 45% survival would be ranked as 1, 2, and 3. Thus, no indication would be given that there was a greater difference between the 0% and 40% survival results than the 40% and 45% results. Classical multi-dimensional scaling (CMD) can be used to represent multi-dimensional distances in fewer dimensions for easier display and interpretation (Frank Dillon, EVS Consultants, personal communication, 1997). Two-dimensional plots can be made using CMD to show how the sites differ in their performance of the endpoints. The CMD plot confirms the characteristics of the sites already identified by ranking. In addition, the plots can provide an indication of how far these sites fall outside the normal range.

4.2 APPLICATION OF THE TRIAD APPROACH TO THE DULUTH/SUPERIOR HARBOR

For this study, the number of surficial sites sampled for each component of the Triad (Table 4-2) was as follows:

- sediment chemistry: 80 sites
- sediment toxicity: 44 sites
- benthological community survey: 80 sites (including SUS 8, which was not sampled for chemistry/toxicity, and excluding ERP 4 which was sampled for chemistry only).

Sediment toxicity tests could not be performed at all of the sites due to budget constraints. Therefore, the Triad approach could be applied to a maximum of 44 sites that had all three components. Of this subset of sites, six sites barely failed the toxicity tests for both *H. azteca* and *C. tentans*; these results would need to be interpreted qualitatively rather than quantitatively. Eleven additional sites failed the toxicity test for *C. tentans* at too great of a level to even evaluate the data qualitatively (i.e., 52% control survival was observed rather than the minimum requirement of 70%). Therefore, a weighting factor would need to be applied to compensate for the paired toxicity tests that had excessive control mortality in the batch of eleven *C. tentans* samples.

Kimball's Bay was not an appropriate reference site for the benthic community survey due to low mean values of total abundance and taxa richness. Both sediment toxicity tests for KMB 4 and KMB 5 barely failed the control survival requirements for *H. azteca* and *C. tentans*. Qualitatively, when the sample survival results were normalized for control survival, the *C. tentans* results for KMB 4 appeared to be toxic. The cause of this toxicity could not be determined.

Because Kimball's Bay was not an appropriate reference site, the Triad data could not be evaluated using the RTR approach. Another approach, the simple ranking system, could not be used consistently for the sediment chemistry results. This was because the suite of contaminants measured at each hotspot area varied depending on the major contaminants of concern determined in the 1993 sediment survey. The MNS, SUS, and WLS sediment chemistry was comparable since all sites had quantitative PAHs, PCBs, mercury, and ammonia data collected in addition to TOC and particle size. As discussed in the following sections of this report, each of the above sites had other contaminants of concern (e.g., heavy metals) which represented a data gap in the 1994 results. Although ranking could be done for the subset of MNS, SUS, and WLS sites, the uncertainty of excluding other contaminants of concern would need to be addressed.

Some of the other hotspot areas (e.g., Howard's Bay) had SEM/AVS measurements, but did not have any PAH or PCB measurements done even though these were designated contaminants of concern at the 1993 sample sites. In order to conduct this study at the number of hotspot sites desired, it was necessary to reduce the number of expensive organic analyses that were conducted. For Howard's Bay, PAHs should be included in any future surveys due to potential sources of PAHs from historical coal piles and coal-burning ship traffic.

Classical multi-dimensional scaling was not considered for interpreting the triad data. This was because the MPCA lacks the in-house statistical expertise and statistical software necessary to carry out this data evaluation. The data interpretation would also be hindered by not having an appropriate reference site.

4.3 OTHER APPLICATIONS OF THE 1994 DATA SET

In this study, the sediment chemistry data were compared to OMOEE sediment quality guideline values for available contaminants. The MPCA, with assistance from a consultant, will be developing sediment quality guidelines for the St. Louis River Area of Concern during federal fiscal years 1998 - 1999. These biologically-based guideline values will be based on site-specific chemistry/toxicity data and will be augmented with regional and national data, where necessary. The matching sediment chemistry and toxicity data from this study will be pooled with other synoptic data to evaluate correlations between contaminant concentrations and sediment toxicity. In addition, Smith et al. (1996) have developed biologically-based sediment quality assessment values for freshwater systems; their values may provide another valuable benchmark that St. Louis River AOC sediments can be compared to. For future development of hotspot management plans in the St. Louis River AOC, the MPCA plans on comparing sediment quality to our own guideline values. Other jurisdictional guideline (or assessment) values would be used to fill in data gaps for chemicals the MPCA is unable to develop guideline values for.

Of the 44 sites tested for acute toxicity in this survey, ten sites appeared to be toxic to *H. azteca* (Table 3-26); this included two sites that barely failed the control survival requirement of 80%. Seven sites appeared to be acutely toxic to *C. tentans (*Table 3-26); this included two sites that barely failed the control survival requirement of 70%. The cause of this toxicity could not be determined. Detailed sediment Toxicity Identification Evaluation tests would need to be conducted to pinpoint the causative agent(s) responsible for toxicity. Although these types of tests have been successfully used for water column and effluent samples, they are still under development for application to sediment samples.

The Duluth/Superior Harbor is contaminated with bioaccumulative contaminants such as mercury, PCBs, and PAHs. The MPCA will be collecting moderately contaminated sediments from the harbor during the summer of 1998. These sediments will be sent to a toxicology laboratory where 28-day bioaccumulation tests with *Lumbriculus variegatus* will be conducted for mercury, PCBs, and PAHs. This small scope project will help to address the question of how much do these contaminants bioaccumulate in benthic invertebrates.

The mean total abundance for the benthological community ranged from 215 organisms/m^2 at DMIR 1 to 57,051 organisms/m^2 at MNS 2. Differences in abundance between stations may be due to a number of factors, including: 1) differing contaminant levels; 2) variation in substrate, which would preclude colonization by the invertebrates; 3) depth of the station, which may prohibit invertebrates because of wave action or ship/boat traffic; and/or 4) other unmeasured variables (Canfield et al., 1994).

The benthos data collected during this survey will serve as a valuable baseline to compare status and trends of benthological surveys conducted at similar time periods in the future. As part of the R-EMAP project, which is being carried out in the St. Louis River AOC, the benthological community structure of 140 sites (most randomly selected) is being statistically compared to physical (e.g., particle size, TOC), chemical (i.e., screening PAHs, mercury, AVS/SEM), and sediment toxicity test results (i.e., Microtox and 10-day toxicity tests with *H. azteca* and *C. tentans*). Based on preliminary results, some of the variance in the R-EMAP benthological data appears to be due to physical factors which affect the type of habitat available to them. At several sites in this survey, the benthological community was dominated by pollution-tolerant organisms that were able to withstand the stresses of a low oxygen environment. Although dissolved oxygen was not measured in this survey, several of the major organisms found in this survey had physiological/behavioral adaptations to increase their ability to absorb oxygen from the overlying water. The high species richness that occurred at some of the sites (e.g., Minnesota Slip) was due to the high number of pollutant-tolerant taxa rather than a diverse assemblage of organisms.

4.4 DEVELOPMENT OF HOTSPOT MANAGEMENT PLANS

One goal of this study was to use the Triad approach to assist the MPCA in developing sediment management plans for hotspot areas in the Duluth/Superior Harbor. The Triad data interpretation would have been one component of this process. Phase II of the RAP Sediment Strategy for the St. Louis River AOC lists the following components for the development of hotspot management plans:

- determine potentially responsible parties
- determine community goals for the site
- determine clean-up goals
- map site to determine extent of problem and volume of contaminants
- develop remediation scenarios with costs
- conduct a feasibility study
- explore potential sources of funds.

The above factors will need to be developed through remediation scoping projects at designated hotspot sites. This process is currently taking place at the Slip C site. Additional sediment core sampling for quantitative PAHs, PCBs, mercury, lead, TOC, and particle size was conducted during June 1997. These data will be pooled with previously collected data to develop three-dimensional maps of sediment contamination, at depth, in Slip C. From these maps, volumes of contaminants will be estimated. Other sites recommended for remediation scoping projects are listed in the next chapter of this report.

CHAPTER 5

RECOMMENDATIONS

This study provided key information on contaminant distributions, benthological community structure, and potential sediment toxicity at hotspot areas in the Duluth/Superior Harbor. As such, this study accomplished the assessment goals of the RAP sediment strategy. The database arising from this study will provide a valuable link with other sediment data generated for the Duluth/Superior Harbor. This data compilation will allow Minnesota and Wisconsin state agencies to move forward to Phase II of the RAP strategy: development of hotspot management plans. The MPCA is already conducting a sediment remediation scoping project at Slip C which will result in a hotspot management plan. For the USX and Interlake/Duluth Tar Superfund sites, the MPCA Site Response section is working towards Phase III of the RAP strategy (i.e., implementation of a remediation action). Similarly, sediment remediation is being planned for the Newton Creek and Hog Island Inlet contaminated area in Superior.

In the 1993 sediment survey report, several general recommendations were made for the management of contaminated sediments in the harbor (Schubauer-Berigan and Crane, 1997). For this study, recommendations are listed below which pertain to the results of this survey.

- Conduct sediment remediation scoping projects at the following hotspot sites [recommend using a risk-based approach which utilizes local or regional sediment quality guidelines (to be developed in FY98-99 by the MPCA) to screen contaminants of concern]:

    - Minnesota Slip: contaminants of concern for this slip should include PAHs, PCBs, and mercury. In addition, the following contaminants, which exceeded the OMOEE LEL guideline values at the 1993 sample sites, should be considered: cadmium, chromium, copper, lead, nickel, zinc, and p,p'-DDD + o,p'-DDT. Toxaphene has also been detected in this slip. TOC and particle size would be important ancillary measurements. Sampling should be prioritized in the middle part of the slip.

    - WLSSD/Coffee and Miller Creek Embayment: contaminants of concern for this area should include PAHs, PCBs, mercury, and ammonia. In addition, the following contaminants, which exceeded the OMOEE LEL guideline values at the 1993 sample sites, should be considered: arsenic, cadmium, chromium, copper, lead, nickel, zinc, dieldrin, p,p'-DDE, and p,p'-DDD + o,p'-DDT. Other contaminants (i.e., dioxins, furans, toxaphene) detected in the 1993 survey should be considered as well. TOC and particle size would be important ancillary measurements. A sediment remediation scoping project for this site could be tied into a proposed 21st Ave. West Channel habitat enhancement project.

    - Howard's Bay: contaminants of concern for this area should include arsenic, lead, copper, nickel, zinc, and mercury. In addition, the following contaminants, which exceeded the OMOEE LEL guideline values at the 1993 sample sites, should be considered: PAHs, PCBs, aldrin, dieldrin, and p,p'-DDE. TOC and particle size would be important ancillary measurements. The area around Howard's Bay used to have many historical coal pile storage areas, as well as the historical production of coal-powered ships. Thus, PAHs are an important contaminant to include in any future surveys of this area. The 1993 sediment site near Fraser Shipyards also had the highest aldrin and dieldrin levels observed in that survey (Schubauer-Berigan and Crane, 1997) and should be evaluated further.

  - Embayment surrounding the M.L. Hibbard plant/DSD No. 2 and Grassy Point: contaminants of concern for this area should include PAHs, mercury, and zinc. In addition, the following contaminants, which exceeded the OMOEE LEL guideline values at the 1993 sample sites, should be considered: arsenic, chromium, PCBs, and p,p'-DDD + o,p'-DDT. TOC and particle size would be important ancillary measurements.

  - Superior WWTP: contaminants of concern for this area should include PCBs and mercury. PAHs were measured at only one core in the 1994 survey and were found to be elevated; thus, additional information needs to be collected on the distribution of PAHs at this site. In addition, the following contaminants, which exceeded the OMOEE LEL guideline values at the 1993 sample sites, should be considered: arsenic, cadmium, chromium, copper, lead, nickel, and zinc. TOC and particle size would be important ancillary measurements.

- Promote the funding and implementation of a habitat enhancement project at the 21st Avenue West Channel, located east of WLSSD. The general concept of this project has wide ranging support from the Harbor Technical Advisory Committee, including the Army Corps of Engineers Detroit District. If funding is secured, this project would allow for the disposal of clean dredged material from Erie Pier into the 21st Avenue West Channel. Clean dredged material could also be used to cap the contaminated sediments in the WLSSD/Coffee and Miller Creek Embayment; a wetland would be created as a result of this action. This project would need to determine contaminant loadings from Coffee and Miller Creeks to ensure the area does not get recontaminated.

- Determine more appropriate reference sites, than Kimball's Bay, for benthological community surveys. The statistically random sampling design of the R-EMAP project may reveal more appropriate reference sites in the St. Louis River AOC.

- Conduct hydrodynamic and sediment transport modeling in the Duluth/Superior Harbor. Hydrodynamic modeling will determine the long-term movement of water masses and associated contaminants in the harbor. Since contaminants are strongly associated with the fine sediment fraction, sediment transport modeling can focus on the dynamics of suspended sediments in the harbor. In particular, the hydrodynamics and sediment transport of Minnesota Slip needs to be studied to determine if contaminants focus in this slip from other harbor sources. This modeling effort will also serve as the basis for any future environmental fate modeling that may be conducted for selected contaminants. In addition, hydrodynamic and sediment transport modeling is needed to address how potential changes to the waterfront (i.e., resulting from remediation) may affect the circulation patterns and sediment transport in the harbor.

- Conduct a contaminant loading study for the Duluth/Superior Harbor (or on a smaller scale for well-defined hotspot areas). Preferably, annual and seasonal loadings would be calculated for WLSSD and the Superior WWTP, as well as for combined sewer overflows, stormwater runoff, and river and creek discharges. This information will be especially important for sites designated to be remediated.

- Discontinue the use of the PAH fluorescence screening technique on sediments from this AOC. Instead, physical observations of the sediment core sections can provide an effective visual screen for samples which should be analyzed for quantitative PAHs. Thus, samples which appear oily or contain fly ash, coal tar, coal particles, and/or wood products should be prioritized for quantitative analysis.

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FIGURES

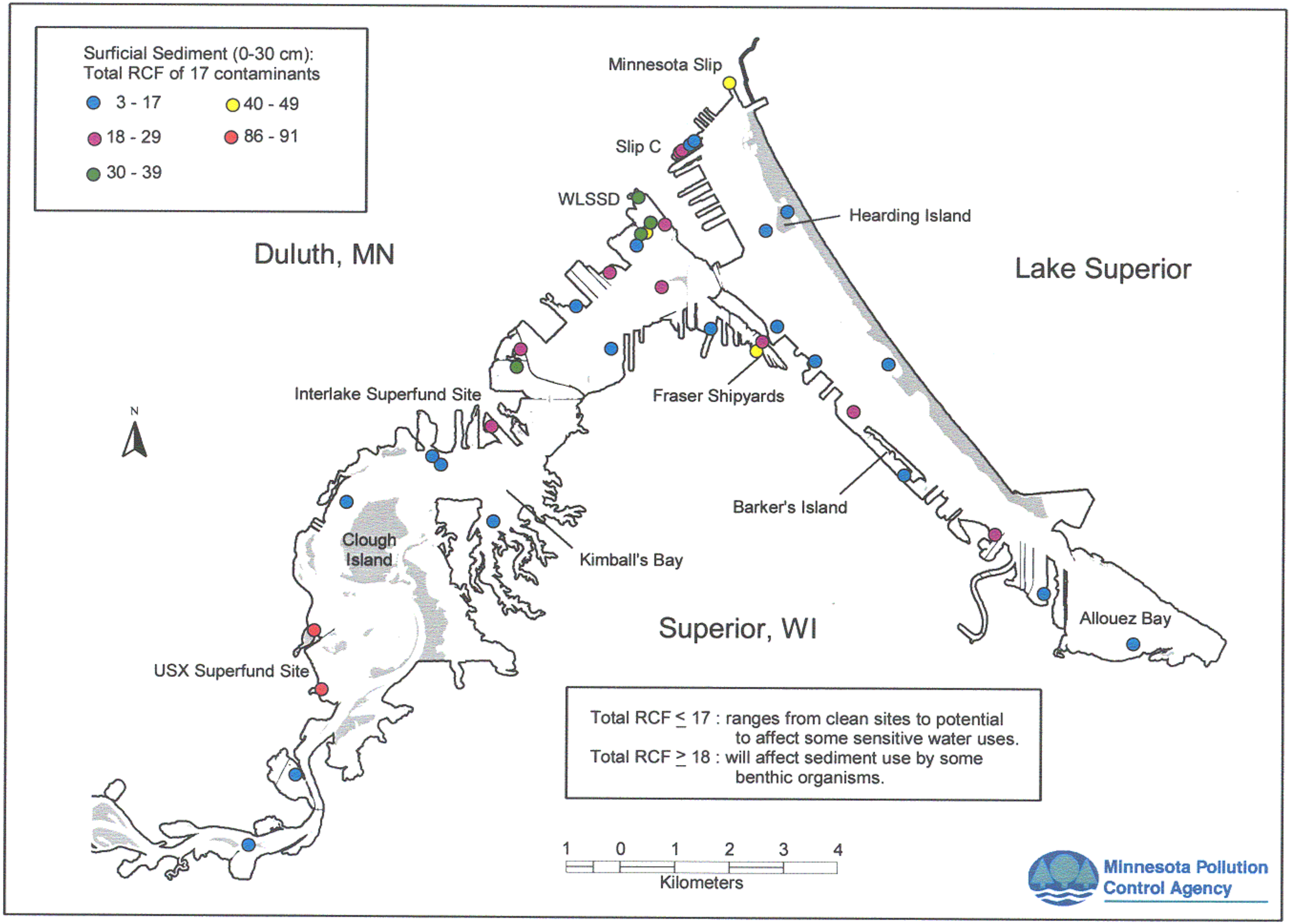

Figure 1-1. Total relative contamination factors (RCFs) for surficial sediments (i.e., 0-30 cm) collected during the 1993 sediment survey of the Duluth/Superior Harbor (Schubauer-Berigan and Crane, 1997). RCF values were calculated for 17 contaminants by normalizing the contaminant concentration by the respective Ontario Low Effect Level (LEL) guideline value.

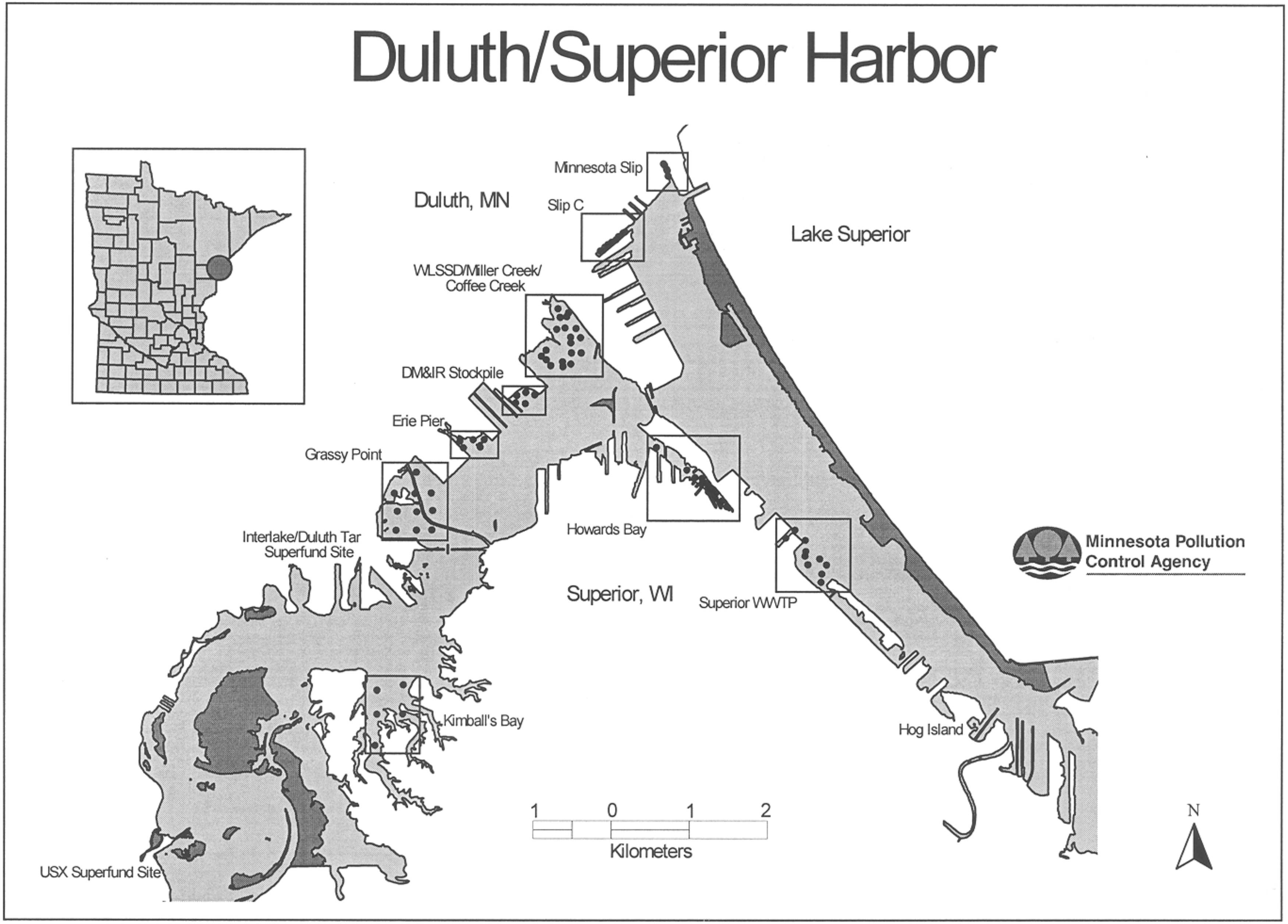

Figure 2-1. Location of study sites.

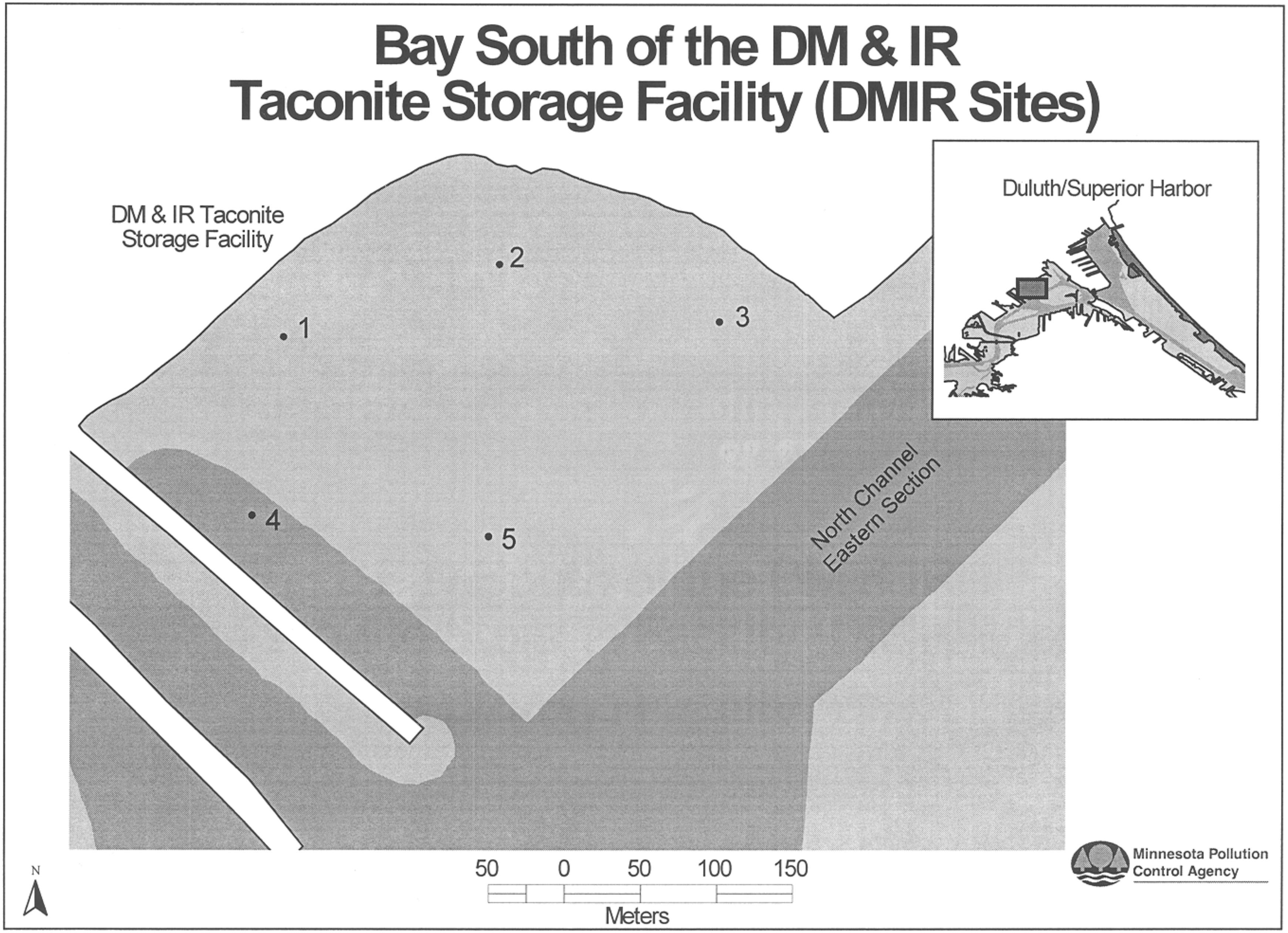

Figure 3-1. Map of DMIR sample sites.

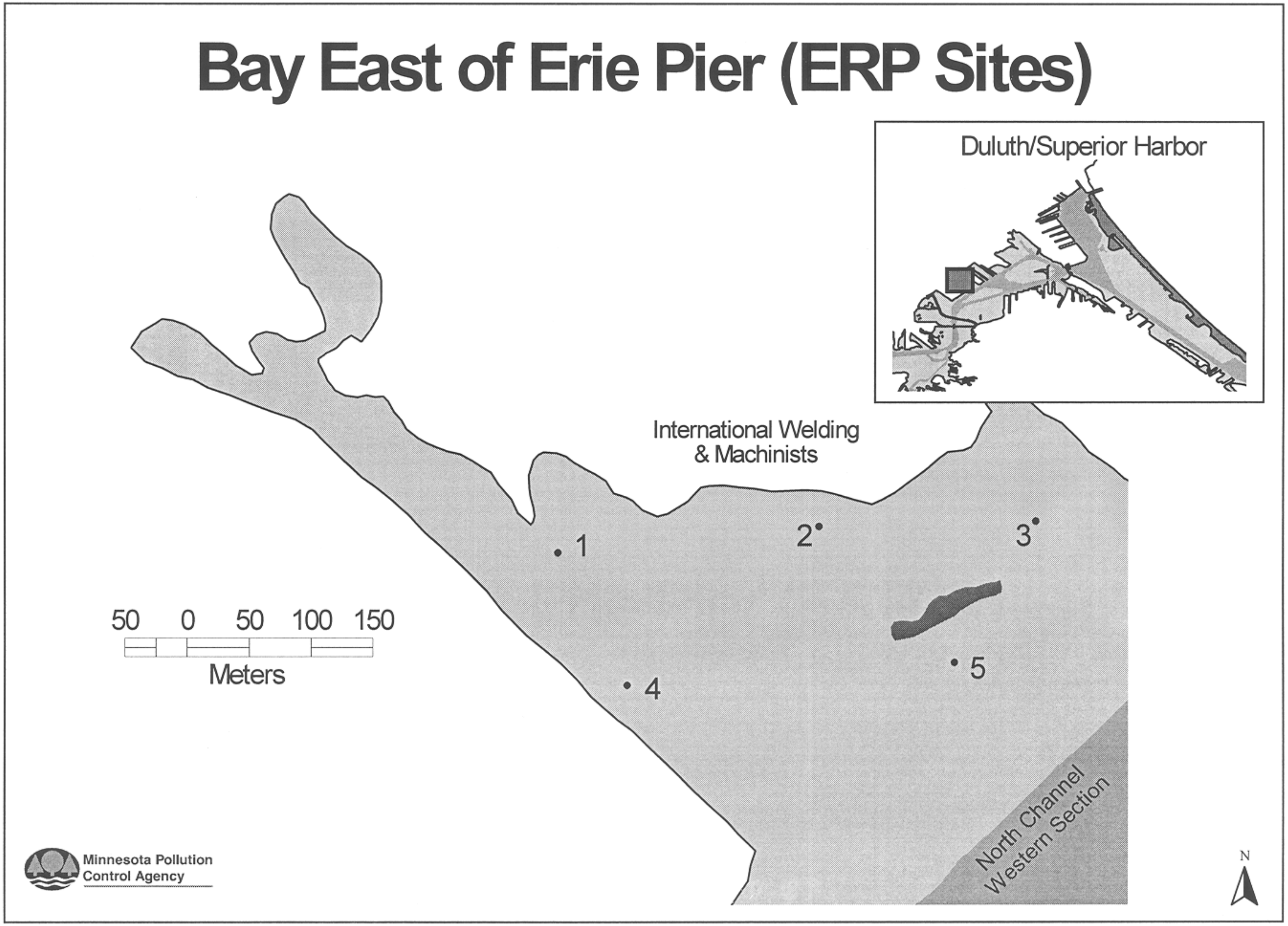

Figure 3-2. Map of ERP sample sites.

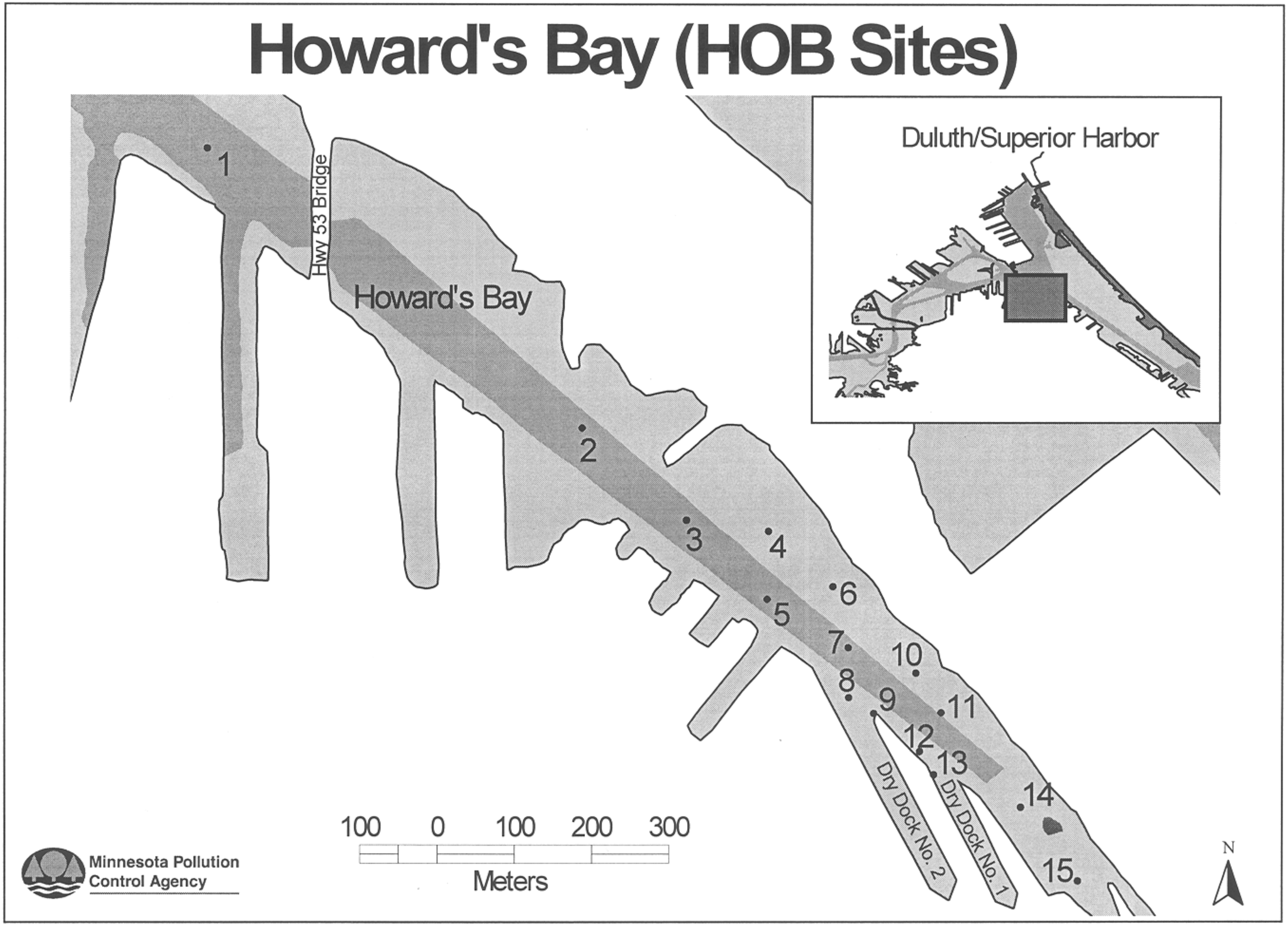

Figure 3-3. Map of HOB sample sites.

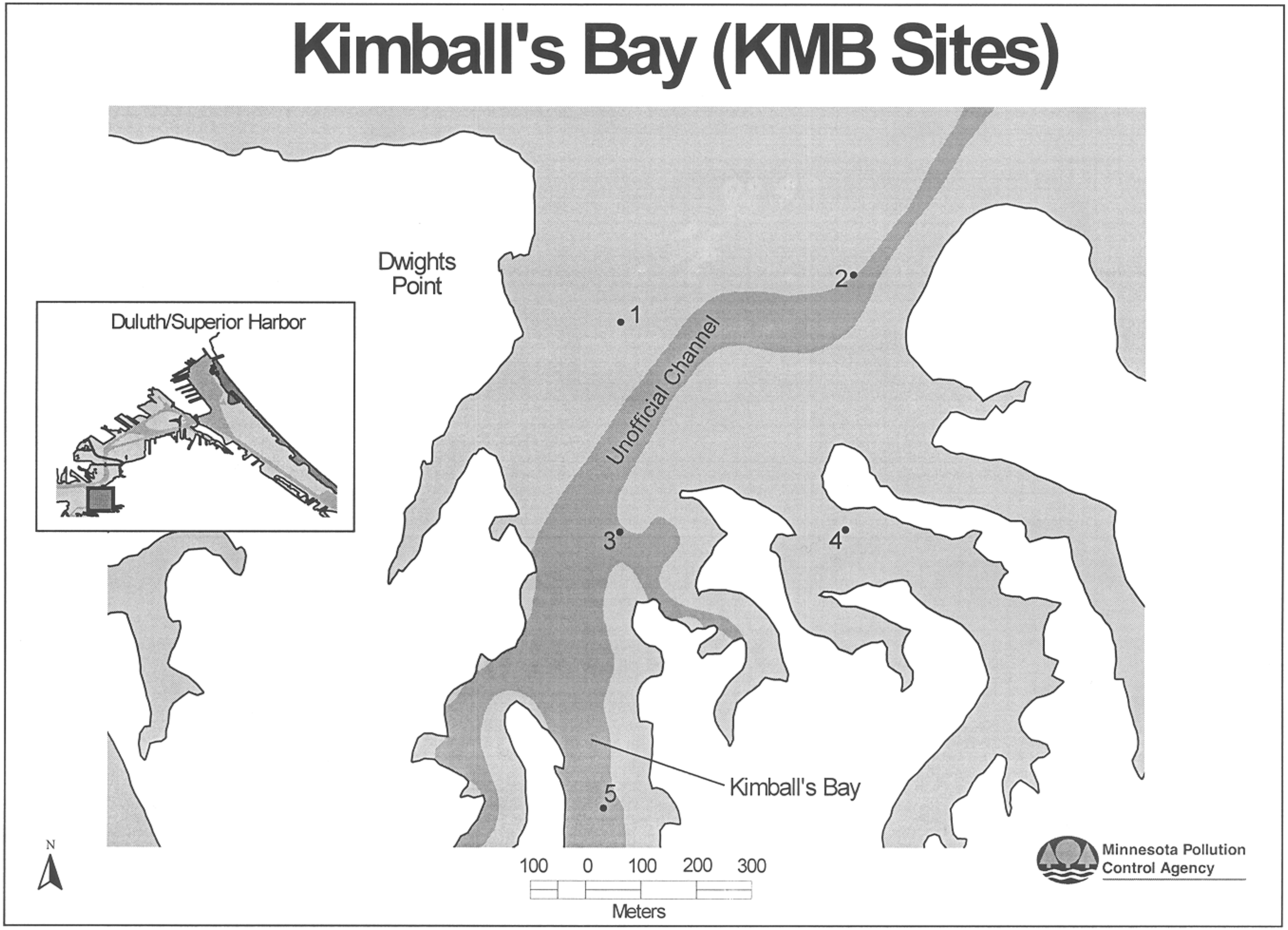

Figure 3-4. Map of KMB sample sites.

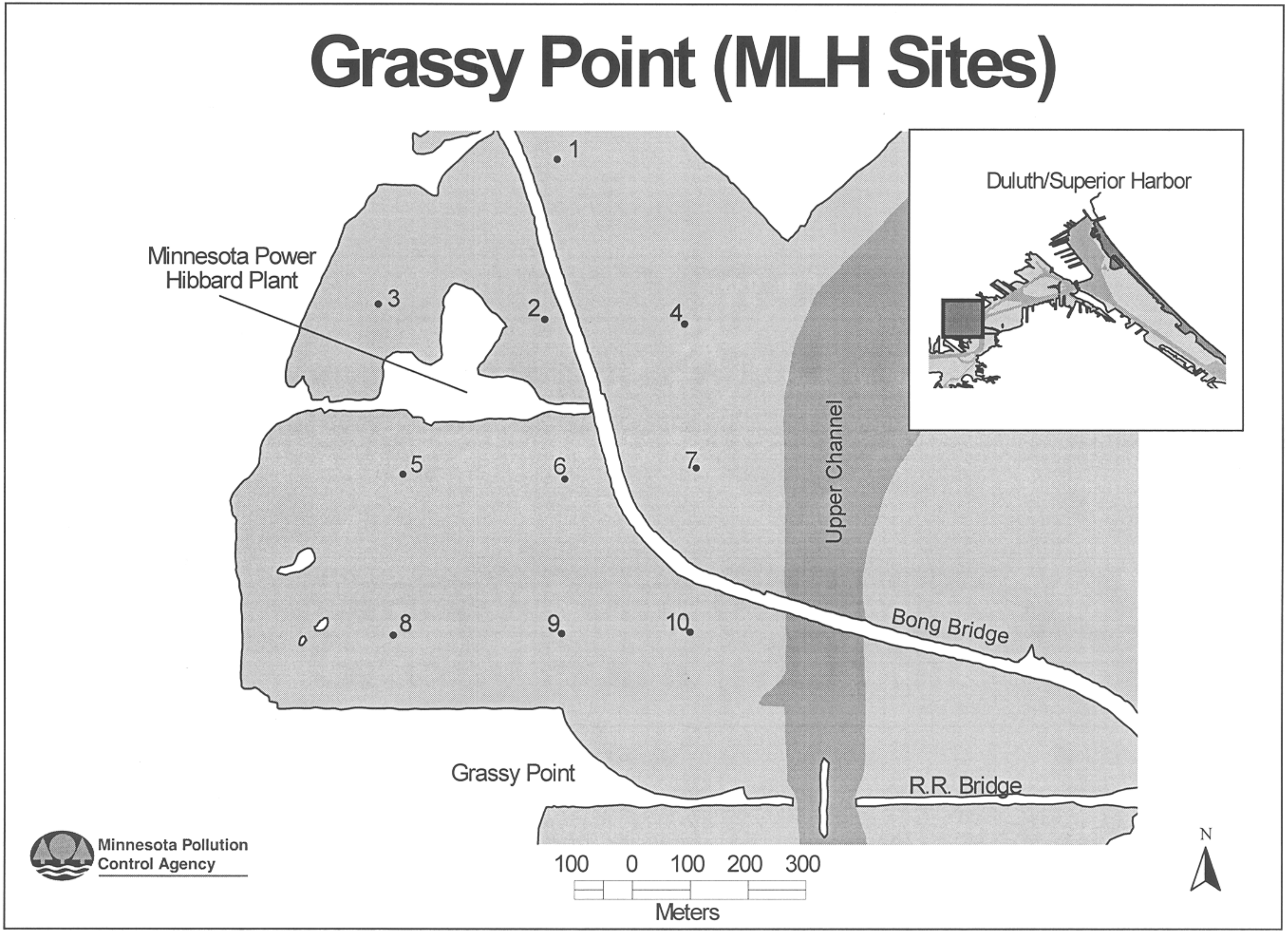

Figure 3-5. Map of MLH sample sites.

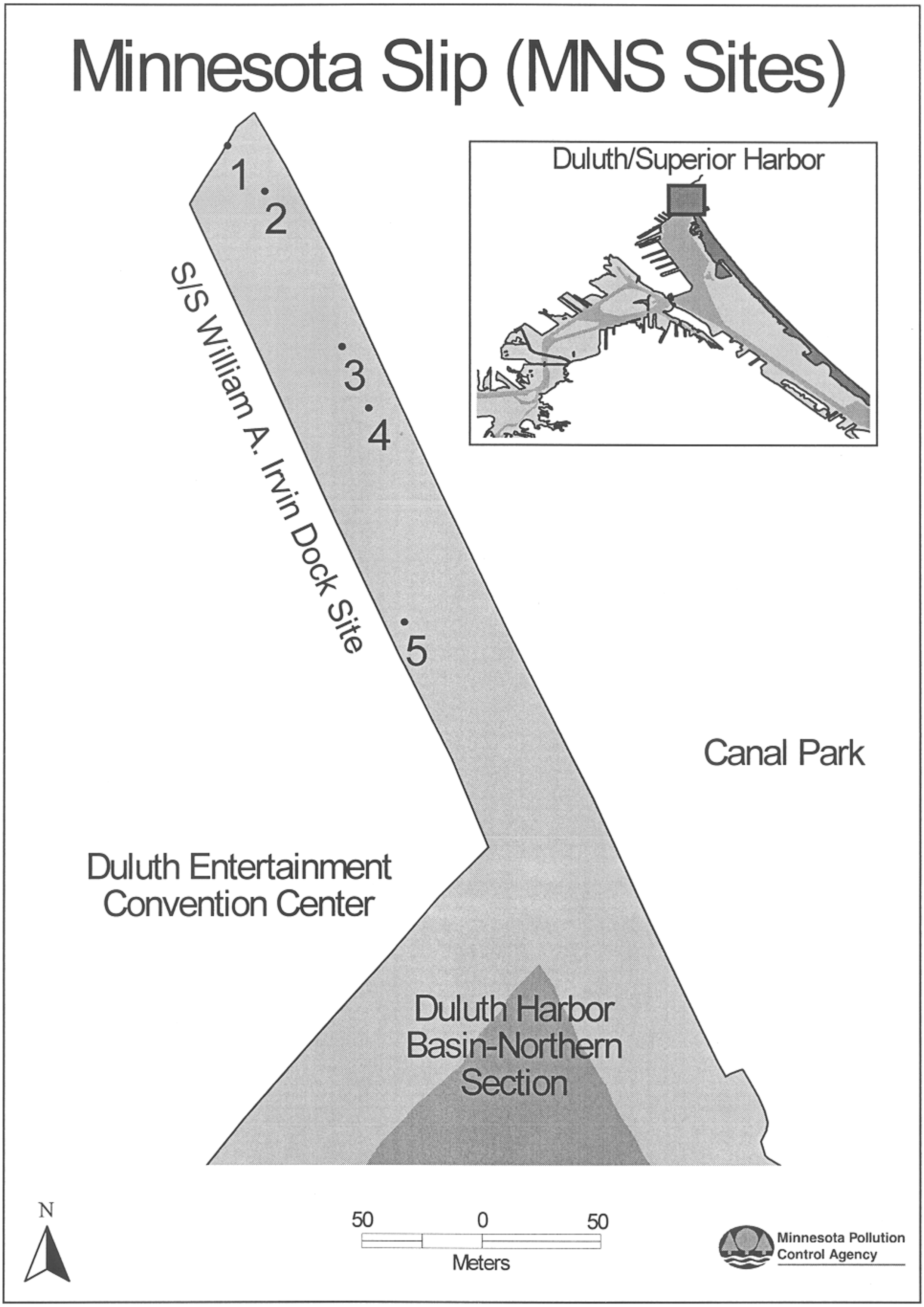

Figure 3-6. Map of MNS sample sites.

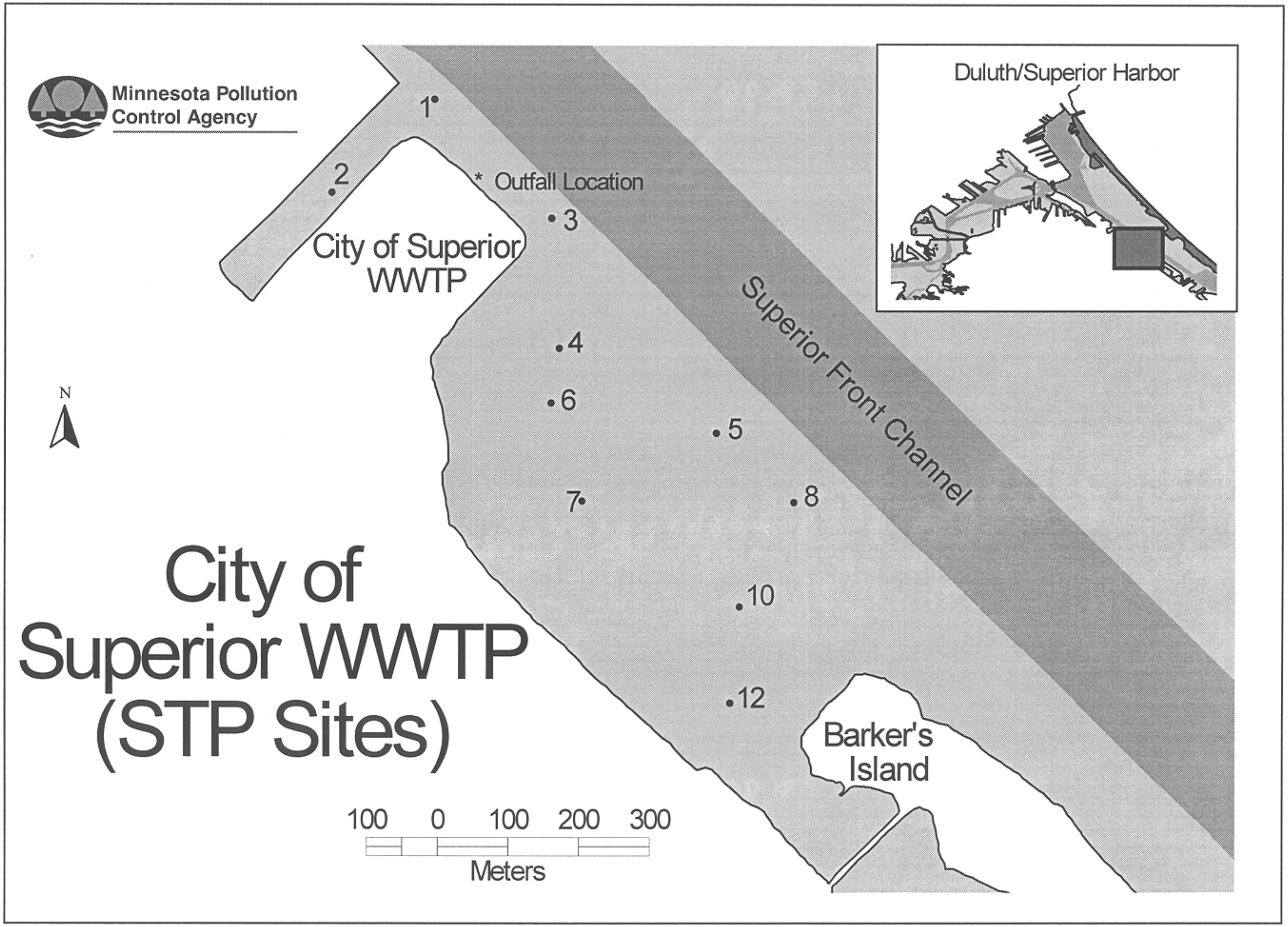

Figure 3-7. Map of STP sample sites.

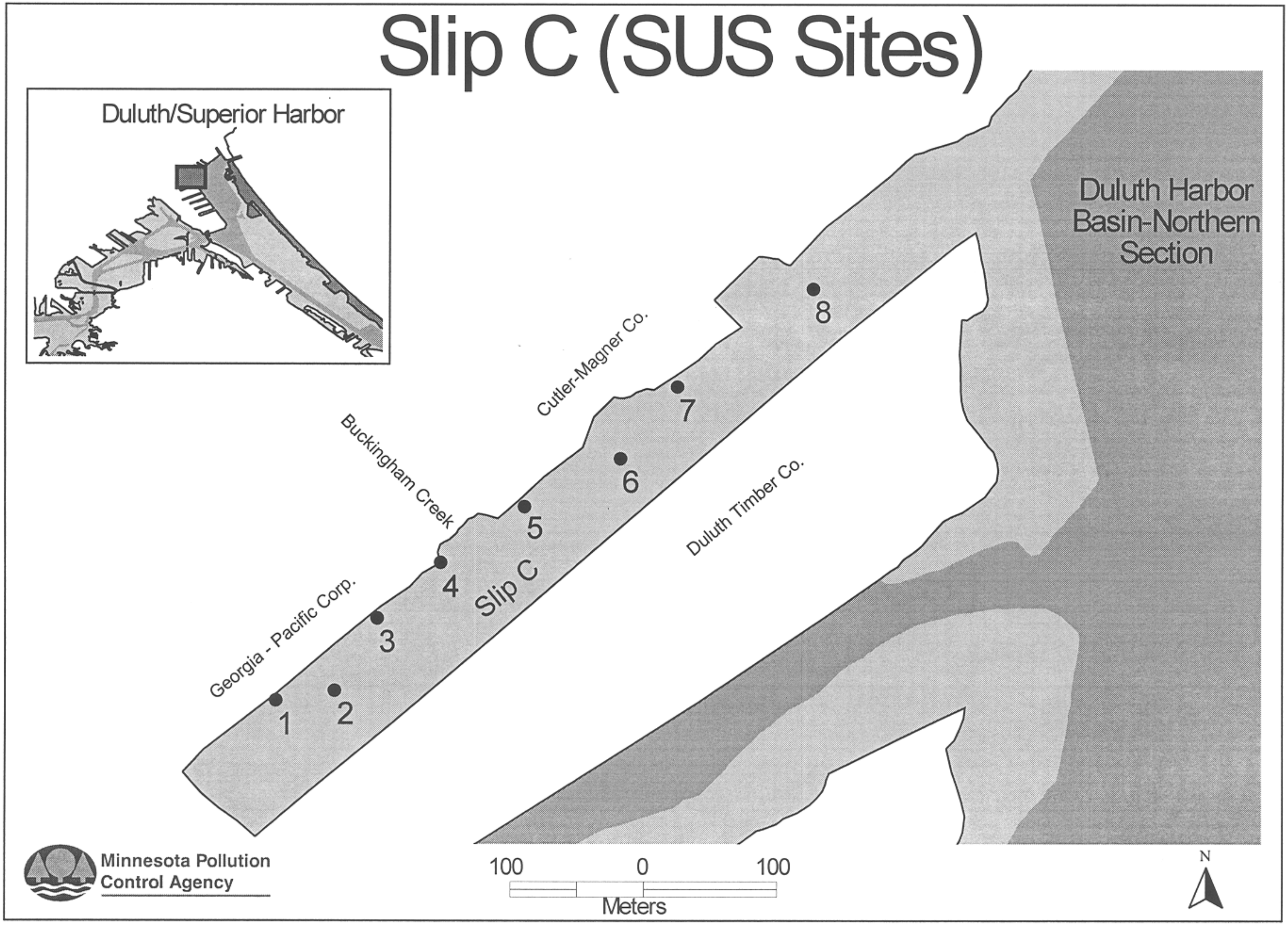

Figure 3-8. Map of SUS sample sites.

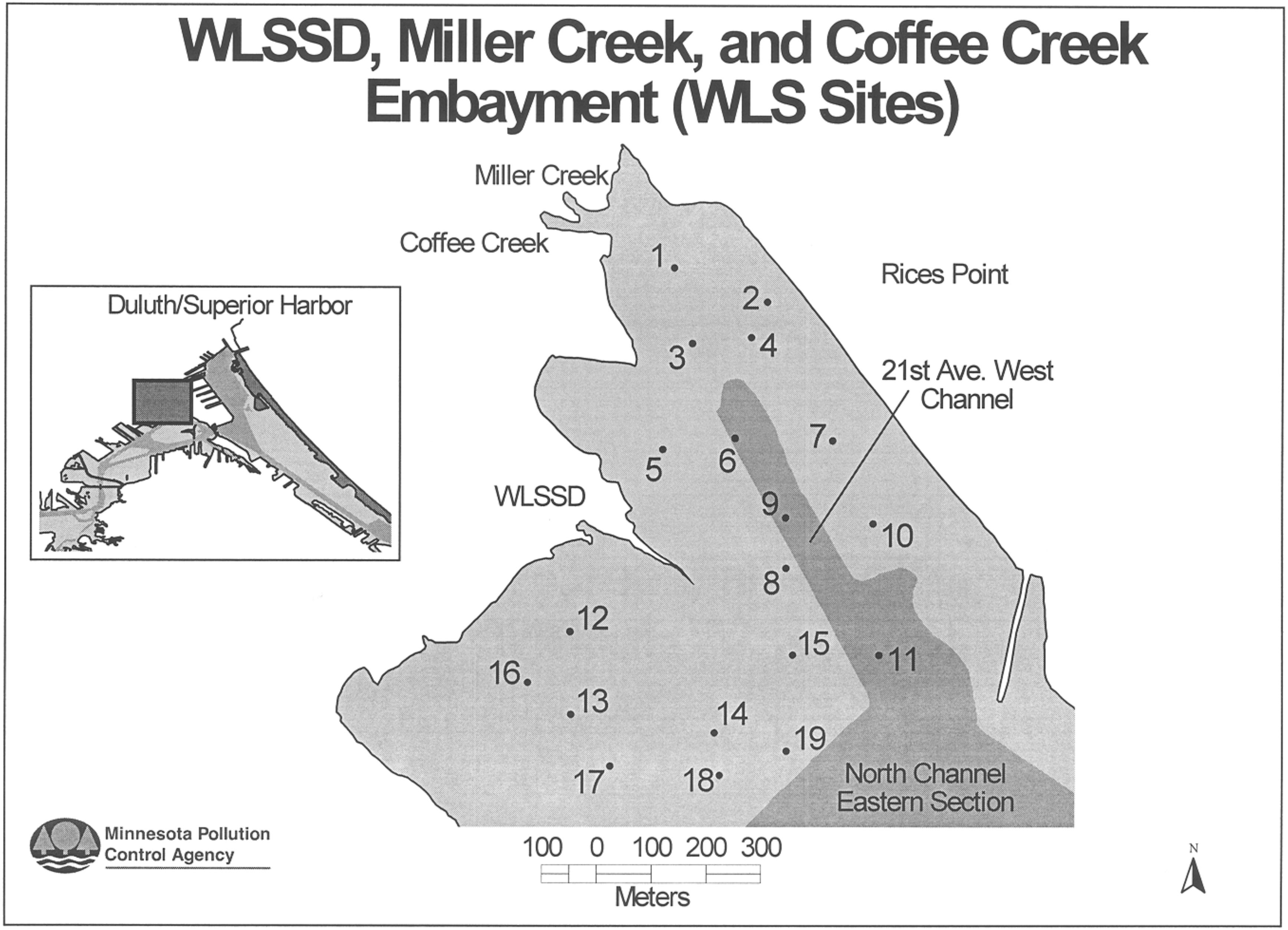

Figure 3-9. Map of WLS sample sites.

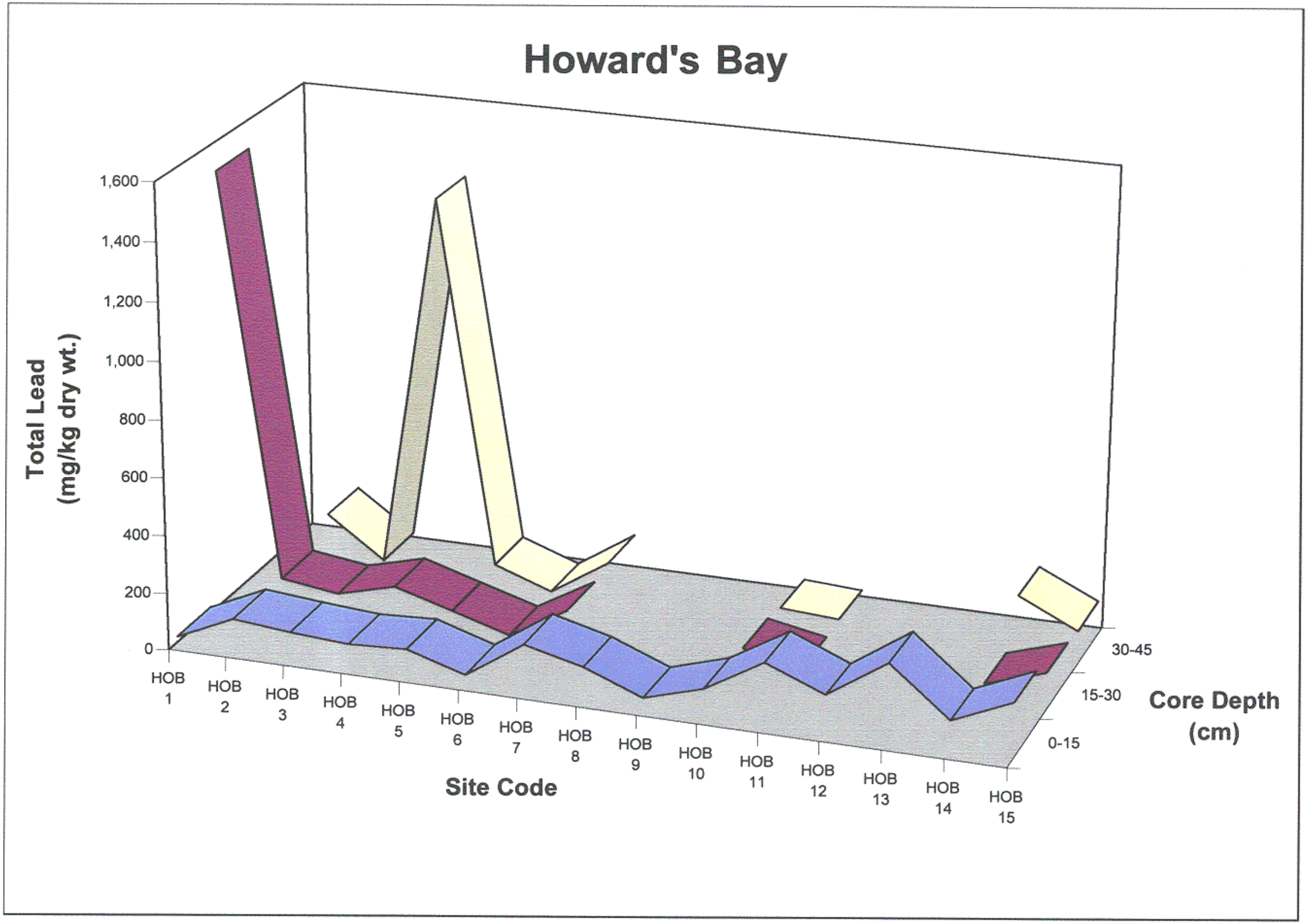

Figure 3-10. Total lead depth profiles for Howard's Bay.

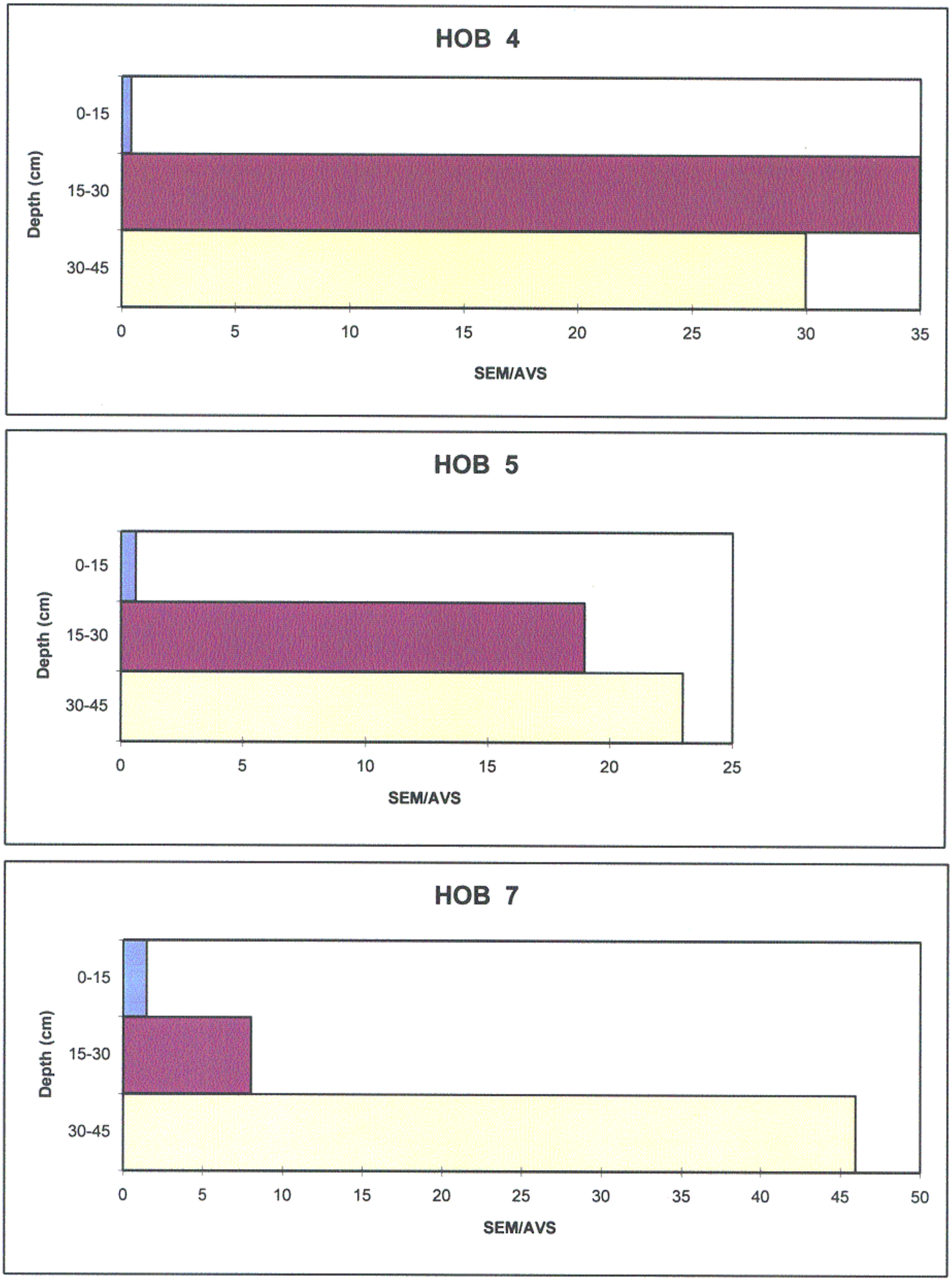

Figure 3-11. SEM/AVS depth profiles for three Howard's Bay sites.

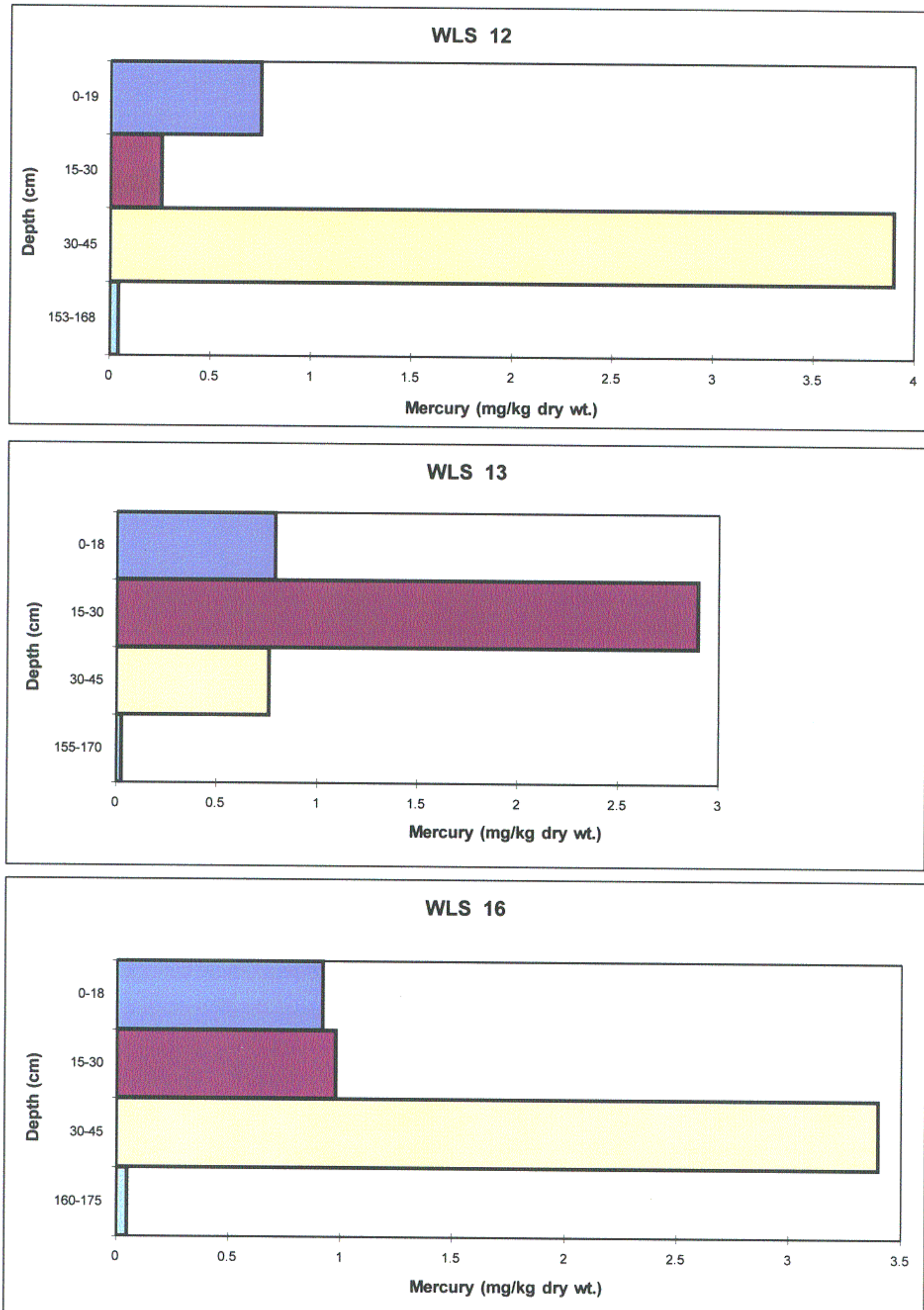

Figure 3-12. Mercury depth profiles for three WLSSD sites.

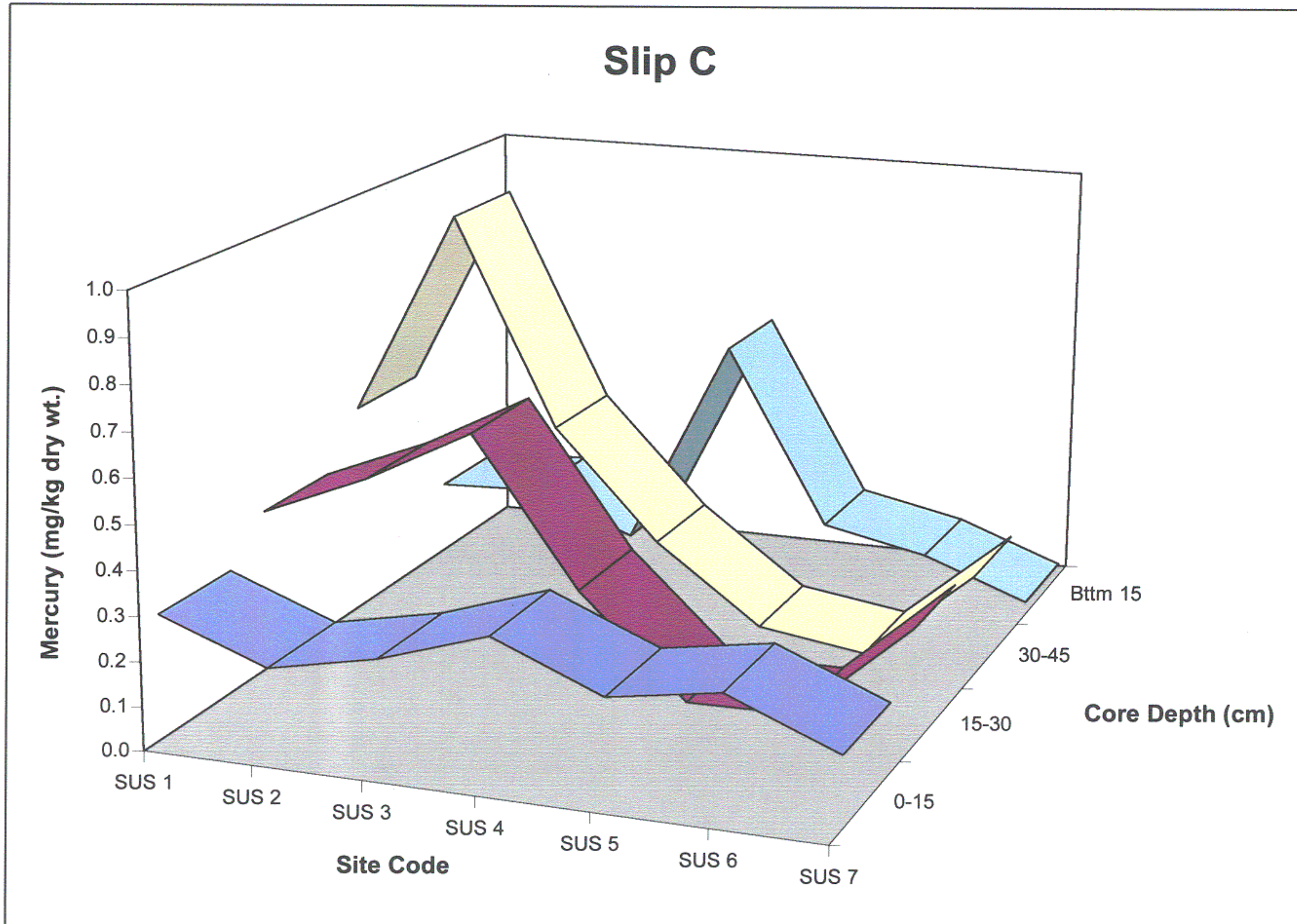

Figure 3-13. Depth profile of mercury at Slip C.

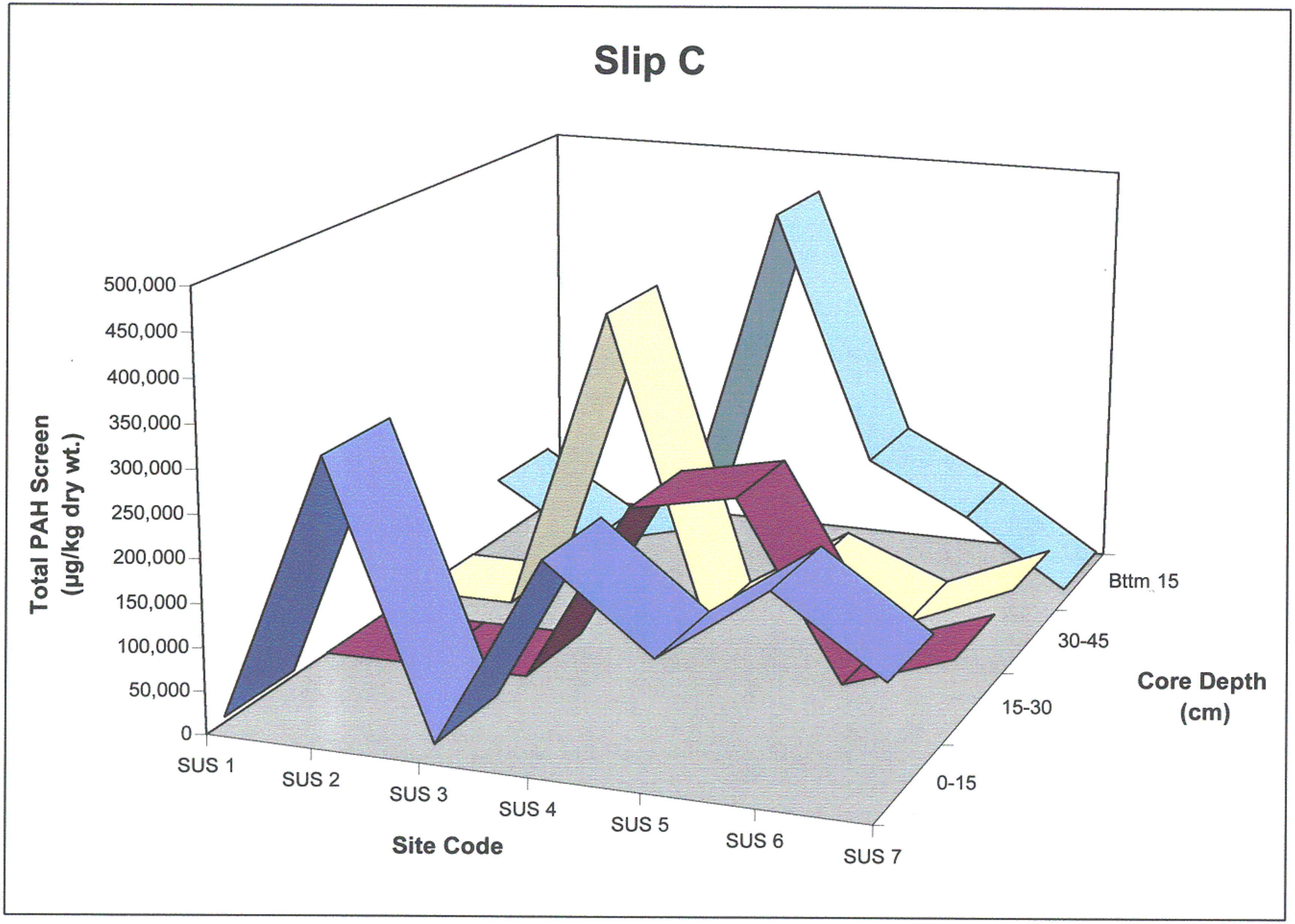

Figure 3-14. Depth profile of screening PAHs at Slip C.

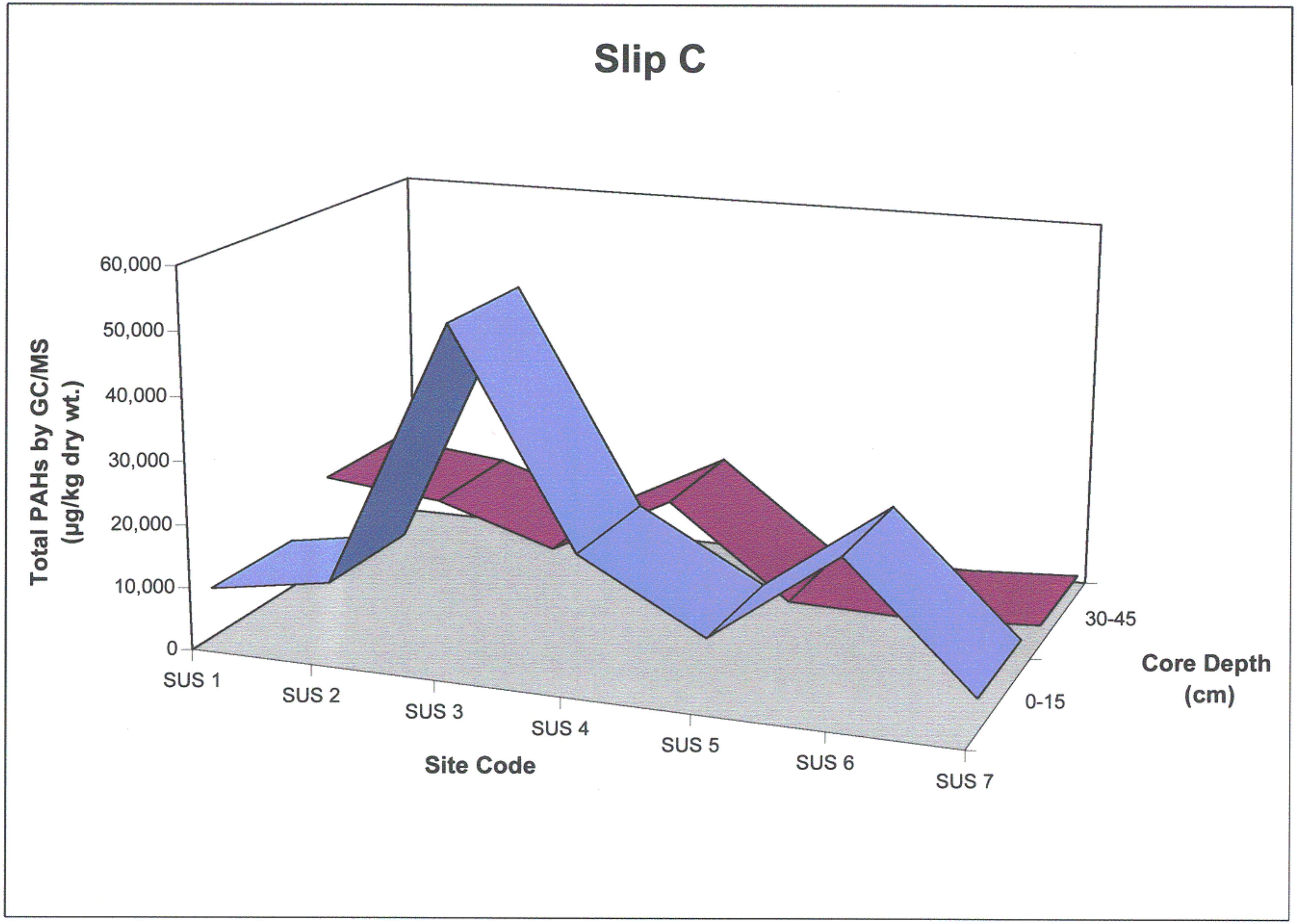

Figure 3-15. Depth profile of total PAHs (by GC/MS) at Slip C.

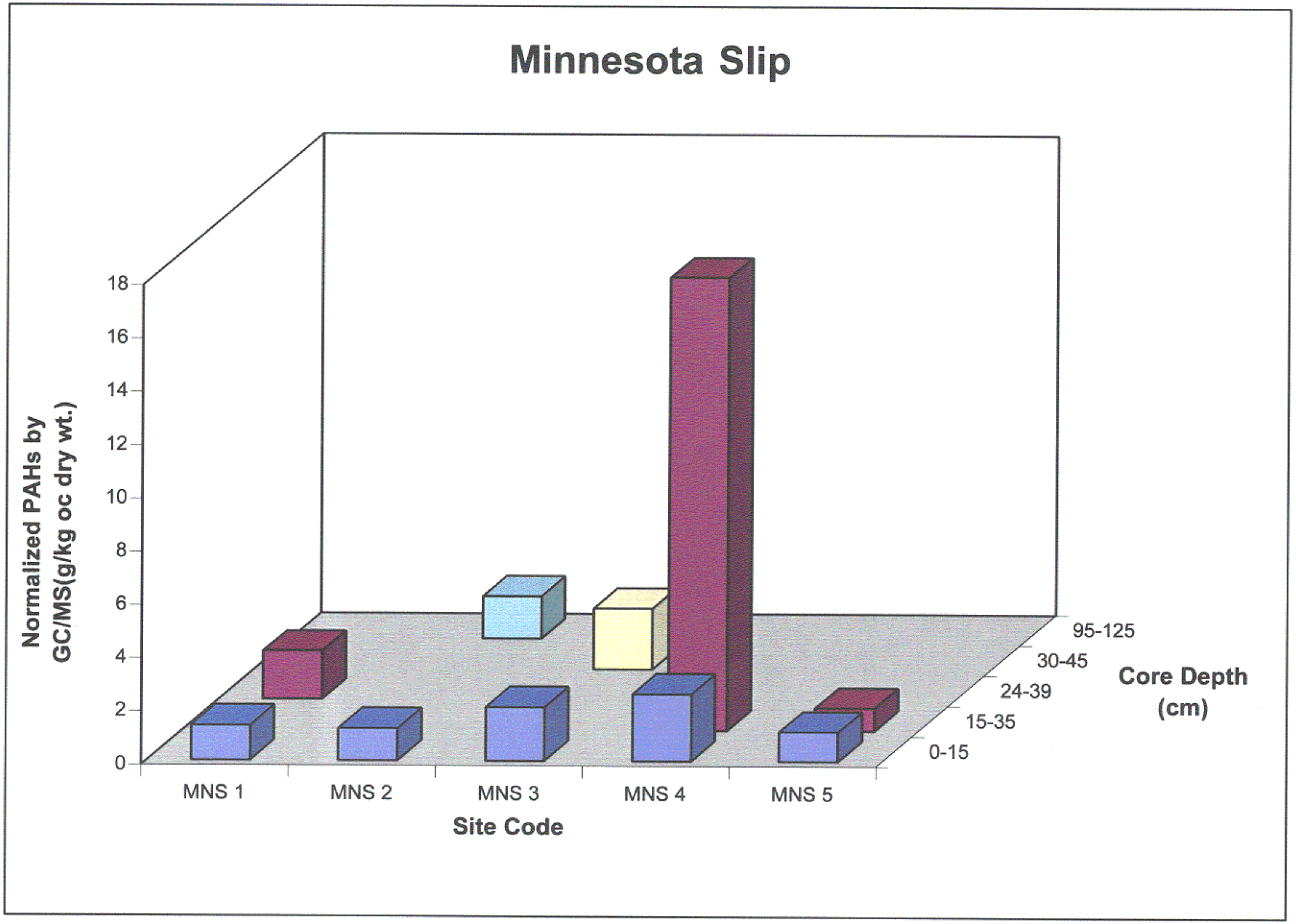

Figure 3-16. Depth profile of normalized PAHs (by GC/MS) at Minnesota Slip.

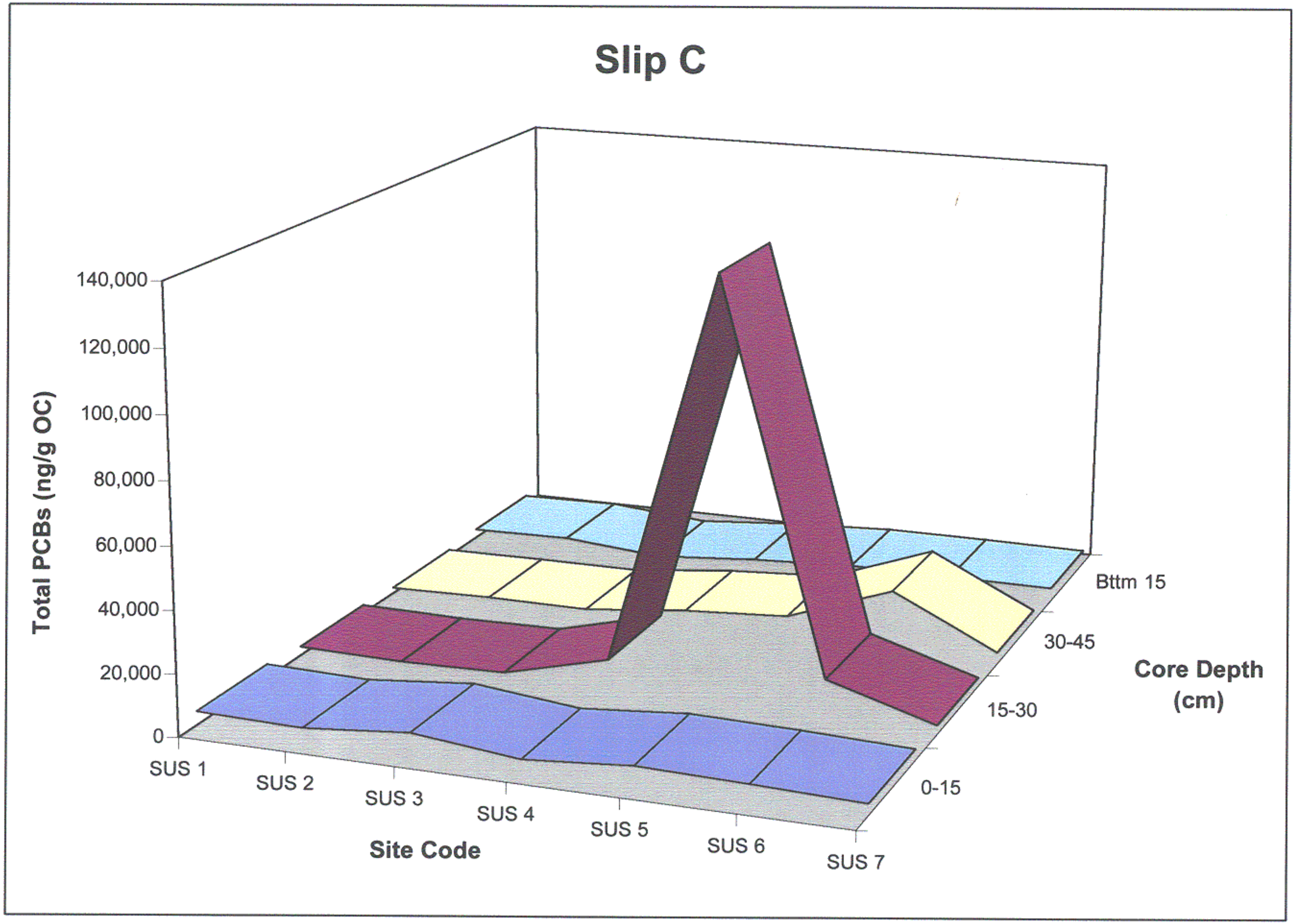

Figure 3-17. Depth profile of normalized PCB concentrations (ng/g oc) at the Slip C sites.

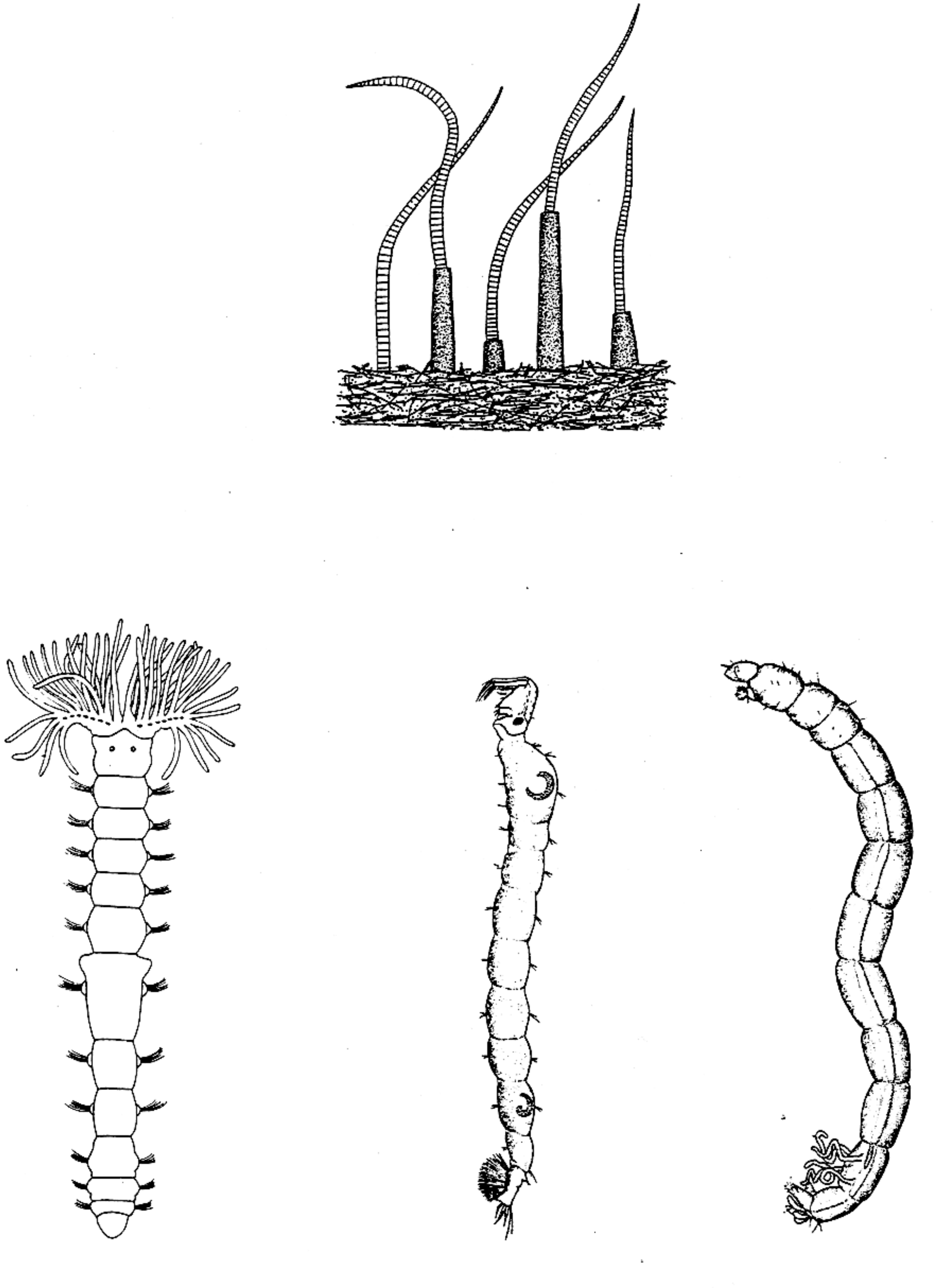

Figure 3-18. Diagrams of: a) Tubificidae, b) *Manayunkia speciosa*, c) Chaoborus, and d) Chironomus (Pennak, 1978).

TABLES

Table 2-1. Sectioning Scheme for Chemical Analyses Performed at each Site

Site	Site Code	Number of Cores	Sections Analyzed	Analyses Performed
DM&IR Stockpile	DMIR	4	0-15 cm	AVS/SEM, TOC, particle size
Erie Pier	ERP	5	0-8 cm	AVS/SEM, NH_3, TOC, particle size
Howard's Bay	HOB	15	0-15 cm & 15-30 cm & 30-45 cm	Hg, Pb, As, AVS/SEM, TOC, particle size
Kimball's Bay	KMB	5	0-15 cm	Hg, TCDD/F, PCBs, PAHs, PAH screen, AVS/SEM, NH_3, TOC, particle size
M.L.Hibbard/ DSD No. 2 and Grassy Point	MLH	10	0-22 cm & Bottom 15 cm	Hg, PAHs, PAH screen, AVS/SEM, TOC, particle size
Minnesota Slip	MNS	5	0-15 cm 15-30 cm 30-45/95-125 cm Bottom 15 cm	Hg, PCBs, PAHs, PAH screen, NH_3, TOC, particle size Hg, PCBs, PAH screen, TOC, particle size Hg, PCBs, PAHs, PAH screen, TOC, particle size Hg, PCBs, PAHs, PAH screen, TOC, particle size
Superior WWTP	STP	10	0-15 cm 15-30 cm 30-45 cm Bottom 15 cm	Hg, PCBs, PAHs (1 core), NH_3, TOC, particle size Hg, PCBs, PAHs (1 core), TOC, particle size Hg, PCBs, PAHs (1 core), TOC, particle size Hg, PAHs (1 core), TOC, particle size

Table 2-1. Continued

Site	Site Code	Number of Cores	Sections Analyzed	Analyses Performed
Slip C	SUS	7	0-21 cm 15-30 cm 30-45 cm Bottom 15 cm	Hg, PCBs, PAHs, PAH screen, NH_3, TOC, particle size Hg, PCBs, PAH screen, TOC, particle size Hg, PCBs, PAHs, PAH screen, particle size Hg, PCBs, PAH screen, TOC, particle size
WLSSD and Miller/Coffee Creek Bay	WLS	19	0-15 cm 15-30 cm 30-45 cm Bottom 15 cm	Hg, TCDD/F, PCBs, PAHs, PAH screen, particle size, TOC, NH_3 Hg, TCDD/F, PCBs, PAH screen, particle size, TOC Hg, PCBs, PAH screen, particle size, TOC Hg, PCBs, PAHs, PAH screen, particle size, TOC, NH_3

Table 2-2. Summary of Sediment Analytical Methods

Analyte	Method (description)	Sample cleanup
2,3,7,8-TCDD & 2,3,7,8-TCDF	SW846 (GC/MS)	acid/base, $AgNO_3$/silica gel, Cu, alumina, carbon
PCBs	EPA SW846--8081 (capillary column GC)	Florisil
PAHs	Method 8270 (capillary column GC)	GPC
Hg	EPA 245.5 (cold vapor AAS)	N/A
As	EPA 206.5 (hydride generation)	N/A
Pb	Nitric acid/hydrogen peroxide digestion. Flame/furnace AAS	N/A
AVS	Allen et al. (1991) (photometer)	N/A
SEM	Allen et al. (1991) (atomic absorption)	N/A
Ammonia	KC1 extraction (Soils method 33.3: exchangeable ammonia)	N/A
TOC	Total organic carbon* Sample ignition method 1	N/A
PAH fluorometric analysis	N/A	None

*Technical Report EPA/COE - 81-1.

Table 3-1. Site Coordinates for the 1994 Sediment Survey

Site ID	Latitude	Longitude	Date
DMIR 1	46°45'02.2"N	92°07'43.0"W	8/23/94
DMIR 2	46°45'03.7"N	92°07'36.4"W	8/23/94
DMIR 3	46°45'02.4"N	92°07'29.6"W	8/23/94
DMIR 4	46°44'58.4"N	92°07'44.1"W	8/23/94
ERP 1	46°44'38.9"N	92°08'26.3"W	10/4/94
ERP 2	46°44'39.5"N	92°08'16.3"W	10/4/94
ERP 3	46°44'39.6"N	92°08'08.0"W	10/4/94
ERP 4	46°44'35.4"N	92°08'23.7"W	10/4/94
ERP 5	46°44'35.9"N	92°08'11.2"W	10/4/94
HOB 1	46°44'34.7"N	92°05'58.2"W	9/27/94
HOB 2	46°44'22.8"N	92°05'35.6"W	9/27/94
HOB 3	46°44'18.9"N	92°05'29.3"W	9/27/94
HOB 4	46°44'18.4"N	92°05'24.3"W	9/27/94
HOB 5	46°44'15.5"N	92°05'24.4"W	9/28/94
HOB 6	46°44'16.0"N	92°05'20.4"W	9/28/94
HOB 7	46°44'13.4"N	92°05'19.5"W	9/28/94
HOB 8	46°44'11.3"N	92°05'19.5"W	9/28/94
HOB 9	46°44'10.6"N	92°05'18"W	9/28/94
HOB 10	46°44'12.3"N	92°05'15.4"W	9/28/94
HOB 11	46°44'10.6"N	92°05'13.9"W	9/28/94
HOB 12	46°44'09.0"N	92°05'16.3"W	9/28/94
HOB 13	46°44'08.0"N	92°05'14.4"W	9/29/94
HOB 14	46°44'06.6"N	92°05'09.1"W	9/29/94
HOB 15	46°44'03.5"N	92°05'05.7"W	9/29/94
KMB 1	46°42'29.0"N	92°09'30.0"W	10/4/94
KMB 2	46°42'31.7"N	92°09'10.2"W	10/4/94
KMB 3	46°42'16.7"N	92°09'11.0"W	10/4/94
KMB 4	46°42'16.7"N	92°09'30.2"W	10/4/94
KMB 5	46°42'00.6"N	92°09'31.8"W	10/4/94
MLH 1*	Missing	Missing	8/22/94
MLH 2*	Missing	Missing	8/22/94
MLH 3*	Missing	Missing	8/22/94
MLH 4*	46°44'12.0"N	92°08'48.0"W	8/24/94
MLH 5*	46°44'02.8"N	92°09'13.6"W	8/24/94
MLH 6*	46°44'02.4"N	92°08'59.0"W	8/24/94
MLH 7*	46°44'03.0"N	92°08'47.1"W	8/24/94
MLH 8*	46°43'52.7"N	92°09'14.6"W	8/24/94
MLH 9*	46°43'52.7"N	92°08'59.4"W	8/24/94
MLH 10*	46°43'52.7"N	92°08'47.8"W	8/24/94
MNS 1	46°47'01.2"N	92°05'51.1"W	9/30/94
MNS 2	46°47'00.6"N	92°05'50.4"W	9/30/94
MNS 3	46°46'58.5"N	92°05'48.9"W	9/30/94
MNS 4	46°46'57.7"N	92°05'48.4"W	9/30/94
MNS 5	46°46'54.8"N	92°05'48.5"W	9/30/94

*Geographical coordinates represent a single, uncorrected measurement.

Table 3-1. Continued

Site ID	Latitude	Longitude	Date
STP 1	46°43'50.9"N	92°04'14.4"W	9/29/94
STP 2	46°43'46.7"N	92°04'21.3"W	9/29/94
STP 3	46°43'45.4"N	92°04'06.7"W	9/29/94
STP 4	46°43'39.5"N	92°04'06.3"W	9/29/94
STP 5	46°43'35.5"N	92°03'55.9"W	9/30/94
STP 6	46°43'37.0"N	92°04'06.9"W	10/3/94
STP 7	46°43'32.5"N	92°04'04.9"W	10/3/94
STP 8	46°43'32.3"N	92°03'50.8"W	10/3/94
STP 10	46°43'27.5"N	92°03'54.5"W	10/3/94
STP 12	46°43'23.1"N	92°03'55.2"W	10/3/94
SUS 1	46°46'16.4"N	92°06'39.2"W	9/22/94
SUS 2	46°46'16.6"N	92°06'37.2"W	9/22/94
SUS 3	46°46'18.3"N	92°06'35.7"W	9/22/94
SUS 4	46°46'19.6"N	92°06'33.5"W	9/22/94
SUS 5	46°46'20.9"N	92°06'30.6"W	9/22/94
SUS 6	46°46'22"N	92°06'27.3"W	9/22/94
SUS 7	46°46'23.7"N	92°06'25.3"W	10/3/94
SUS 8	46°46'26"N	92°06'20.6"W	10/3/94
WLS 1	46°45'46.6"N	92°07'11.5"W	9/21/94
WLS 2	46°45'44.5"N	92°07'03.5"W	9/21/94
WLS 3	46°45'42.1"N	92°07'10.0"W	9/21/94
WLS 4	46°45'42.4"N	92°07'04.9"W	9/23/94
WLS 5	46°45'35.9"N	92°07'12.6"W	9/23/94
WLS 6	46°45'36.5"N	92°07'06.4"W	9/23/94
WLS 7	46°45'36.3"N	92°06'58.0"W	9/23/94
WLS 8	46°45'28.8"N	92°07'02.1"W	9/23/94
WLS 9	46°45'31.8"N	92°07'02.1"W	9/23/94
WLS 10	46°45'31.4"N	92°06'54.6"W	9/23/94
WLS 11	46°45'23.6"N	92°06'54.2"W	9/23/94
WLS 12	46°45'25.2"N	92°07'20.7"W	9/26/94
WLS 13	46°45'20.3"N	92°07'20.7"W	9/26/94
WLS 14	46°45'19.1"N	92°07'08.4"W	9/26/94
WLS 15	46°45'23.7"N	92°07'01.6"W	9/26/94
WLS 16*	46°45'22.2"N	92°07'24.4"W	9/26/94
WLS 17*	46°45'17.2"N	92°07'17.4"W	9/26/94
WLS 18*	46°45'16.6"N	92°07'08.0"W	9/27/94
WLS 19*	46°45'18.0"N	92°06'01.0"W	9/27/94

* Geographical coordinates result from a single, uncorrected measurement at starred sites

Table 3-2. Description of Field Results for DM&IR, Erie Pier, and Kimball's Bay Areas (DMIR 1-4, ERP 1-5, and KMB 1-5)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
DMIR 1*	6.1	1	1	1	NA	1	0-15	Other field information not recorded
DMIR 2*	10.7	1	1	1	NA	1	0-15	“ “ “ “ “
DMIR 3*	5.2	1	1	1	NA	1	0-15	“ “ “ “ “
DMIR 4*	8.8	1	1	1	NA	1	0-15	“ “ “ “ “
ERP 1	1.04	3	21	8	NA	1	0-8	Loose clay over stiff clay; surface algae and detritus
ERP 2	0.67	3	18	9	NA	1	0-8	Oxidized Fe layer (1cm) over red sand
ERP 3	0.89	3	28	9	NA	1	0-5	Thin oxidized Fe layer over red sand
ERP 4	1.13	3	NA	9	NA	1	0-5	Loose silty clay with detritus (2 cm) over stiff brown clay
ERP 5	1.52	3	NA	6	NA	1	0-5	Thin oxidized Fe layer over reddish brown sand
KMB 1	1.83	3	NA	5	NA	1	0-8	Soft brown clay with detritus
KMB 2	2.68	3	NA	7	NA	1	0-12	Thin oxidized Fe layer over soft gray clay
KMB 3	3.26	3	NA	5	NA	1	0-15	Thin oxidized Fe layer over dark brown clay
KMB 4	3.96	3	10	5	NA	1	0-15	Silty brown clay (2 cm) over thicker clay with black streaks
KMB 5	3.05	3	8	5	NA	1	0-15	Soft brown silty clay

* Sample collected with a Ponar.

NA= Not Applicable

Table 3-3. Description of Field Results for Howard's Bay (HOB 1-15)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
HOB 1	9.75	3	NA	4	0.20	1	0-5	Brown sandy clay (slight oil sheen)
						2	0-5 (VC)	Brown sandy clay (slight oil sheen)
						3	5-20 (VC)	Brown sandy clay (slight oil sheen)
HOB 2	8.23	3	NA	3	1.38	1	0-15	Sandy orange clay, some detritus (slight oil sheen)
						2	15-30	Loose sandy clay (slight oil sheen)
						3	30-45	Loose sandy clay with wood and detritus (slight oil sheen)
HOB 3	8.75	2	NA	3	0.45	1	0-15	Sand with shiny particles (5 cm) over pink and brown clay
						2	15-30	Soft brown clay with plant fibers (slight oil sheen)
						3	30-45	Stiff, brick-colored clay
HOB 4	4.33	2	NA	3	1.00	1	0-15	Sand/grit (3 cm) over pink and brown clay
						2	15-30	Soft pink and brown clay
						3	30-45	Soft pink and brown clay with wood detritus
HOB 5	8.90	2	NA	4	0.45	1	0-15	Loose, flocculant, oxidized Fe (3 cm) over soft brown clay
						2	15-30	Dark brown clay (10 cm) over red clay
						3	30-45	Red clay (5 cm) over dark brown clay with some oil smears
HOB 6	1.28	3	NA	3	0.45	1	0-15	Dark gritty sand (2 mm) over red clay (5 cm) over black clay with oily coal chunks (5 cm) over red sand
						2	15-30	Clay with sand and coal chunks, no oil
						3	30-45	Coarse red sand, few pebbles
HOB 7	8.20	2	10	3	0.82	1	0-15	Fluffy silt/clay with black grit (5 cm) over brown clay
						2	15-30	Sandy brown clay, some oil and detritus
						3	30-45	Uniform sandy brown clay with some detritus, less oil

NA= Not Applicable
VC= Vibrocorer

Table 3-3. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
HOB 8	6.80	3	10*	10*	NA	1	0-5	Very sticky red clay. Ponar sample was oily, whereas gravity core samples for benthos were not oily.
HOB 9	7.01	3	NA	7	NA	1	0-5	Fine sandy grit (1 cm) over hard red clay
HOB 10	0.91	3	23	5	0.95	1	0-10	Sandy grit with some clay (oil sheen)
						2	15-30	Dark brown clay with detritus over dark sand with some clay
						3	30-45	Uniform dark brown clay/sand
HOB 11	7.01	2	20	3	0.40	1	0-15	Floccy orange particles (3 cm) over reddish clay
						2	10-25	Uniform stiff red clay with some detritus
						3	25-40	Stiff red clay over brown clay with detritus
HOB 12	5.64	3	20	6	NA	1	0-10	Gritty sand over hard red/gray clay
HOB 13	5.49	3	21	8	NA	1	0-10	Soft, loose clay/silt with gritty sand over red clay
HOB 14	4.36	2	12	3	0.45	1	0-15	Loose, sandy clay over stiffer clay, some oil in tox./chem. samples
						2	15-30	Very stiff red clay with a few rock chips
						3	30-45	Less stiff brown clay with some detritus
HOB 15	3.81	3	14	5	1.20	1	0-10	Dark brown, loose clay with some sand
						2	15-30	Heavy black oil and sand
						3	30-45	Heavy black oil with sand and some wood chunks

NA= Not Applicable

* A Ponar grab sampler was used to collect toxicity and surface chemistry samples due to compacted substrate.

Table 3-4. Description of Field Results for M.L. Hibbard/DSD No. 2 Plant and Grassy Point Embayment (MLH 1-10)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
MLH 1	1.52	1	10	2	0.4	1 Bottom	0-13.5 25-40	Gritty, uniform black/brown sediment Same as upper section
MLH 2	1.04	1	6	2	0.95	1 Bottom	0-22 80-95	Silt with ash throughout, strong sulfide odor, slight oil sheen Uniform, dark granular fly ash
MLH 3	1.52	1	5	2	0.52	1 Bottom	0-20 37-52	Ash with some silt, strong sulfide odor Fine clay/ash over wood chips and detritus
MLH 4	2.13	1	7	2	0.50	1 Bottom	0-20.5 30-50	Very fine brown clay/silt, some ash, oil sheen Soft brown clay over coarse brown sand with wood chips and detritus
MLH 5	2.26	1	6	2	0.47	1 Bottom	0-17.5 32-47	Soft brown clay/silt with oxidized Fe layer on surface Thick brown clay over black ash/wood chips (5 cm)
MLH 6	1.92	1	6	2	0.40	1 Bottom	0-21 25-40	Reddish brown sand with black wood chips, grit, and detritus Uniform sand with fly ash
MLH 7	2.32	1	NA	2	0.87	1 Bottom	0-17 72-87	Soft, light brown sandy clay with some fine black granular material Brown sand with some clay
MLH 8	2.44	1	NA	2	0.76	1 Bottom	0-15.5 60-76	Soft brown clay/silt with some wood fibers Coarse brown sand
MLH 9	2.53	1	NA	2	0.79	1 Bottom	0-22 52-79	Soft brown silty clay with some wood chips and black striations Gray clay and wood fibers (12 cm) over densely packed wood fibers
MLH 10	3.20	1	NA	2	0.95	1 Bottom	0-21 75-95	Soft brown silty clay Brown clay with black bands of undecomposed organic fibers

NA= Not Applicable

Table 3-5. Description of Field Results for Minnesota Slip (MNS 1-5)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
MNS 1	5.03	3	17	6	0.54	1	0-10	Soft, oily silt/clay
						2	9-24	Black, oily sand/silt/clay with some detritus
						3	24-39	Black, very oily sand/clay
						4	39-54	Very oily, stiffer black sand/clay
MNS 2	5.00	3	NA	6	1.60	1	0-12	Loose, dark brown silt/clay
						2	15-30	Black, oily, sandy clay with some detritus
						3	95-125	Black, oily, sandy clay
						4	145-160	Uniform, black oily sand (with white bits and red fibers)
MNS 3	5.06	3	13	3	0.60	1	0-15	Gritty silty/clay over silt and some oil/detritus
						2	15-30	Soft, oily silt/clay with some detritus
						3	30-45	Soft, brown clay (3 cm) over oily detritus (5 cm) over non-oily reddish sand
						4	45-60	Oily reddish sand, little detritus
MNS 4	4.88	3	NA	4	0.60	1	0-15	Loose, oily clay (5 cm) over stiff clay
						2	0-15 (VC)	Loose clay (3 cm) over oily sand with detritus
						3	15-30	Very coarse sand, slightly oily, large rocks
						4	30-45	Fine sand, no oil, some detritus
MNS 5	4.27	3	NA	5	0.65	1	0-10	Silt with detritus over soft clay (slight oil sheen)
						2	5-20	Coarse red sand over detritus over sand, no oil
						3	20-35	Very coarse, rocky sand
						4	35-50	Rocks and detritus with oil smell (slight oil sheen) over coarse sand

NA= Not Applicable
VC= Vibrocorer

Table 3-6. Description of Field Results for City of Superior WWTP Embayment (STP 1-8, STP 10, STP 12)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for		Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
			Toxicity	Chemistry				
STP 1	7.01	2	22	4	0.82	1	0-15	Floccy orange mat (3 cm) atop loose sandy clay; tox./chem samples had slight oil sheen
						2	15-30	Loose dark brown clay with detritus
						3	30-45	Dark brown clay/sand, slight oil sheen
STP 2	4.02	2	NA	7	0.25	1	0-15	Dark brown clay/sand (10 cm) over more gray/black clay/sand
						2	10-25	Sand with a bit of clay, strong sulfide odor and oil
STP 3	3.60	2 (A) 3 (B&C)	15	6	0.60	1	0-10	Sandy grit atop clay/sand with some detritus, slight oil sheen
						2	15-30	Fine brown sand with some detritus
						3	30-45	Fine brown sand (5 cm) over coarse red sand
STP 4	2.44	2	13	6	0.96	1	0-15	Oxidized granular layer (5 cm) over soft, gray-brown clayey sand
						2	15-30	Soft, uniform brown clay, little detritus
						3	30-45	Stiffer, uniform brown clay
STP 5	3.17	2	NA	4	NA	1	0-15	Oxidized Fe layer (1 cm) over soft brown clay/silt
STP 6	2.13	2	13	3	0.38	1	0-15	Oxidized Fe layer atop soft silt/clay with detritus
						2	7-23	Large wood chunks over soft silt/clay
						3	23-38	Stiffer brown clay
STP 7	2.31	2	12	4	0.23	1	0-15	Thin oxidized Fe layer over red clay (7 cm) over brown clay, slight oil sheen
						2	5-23	Loose brown clay with wood chunks and oil sheen over sand
STP 8	3.20	2	NA	4	0.30	1	0-15	Thin oxidized Fe layer over silt/clay over brown clay
						2	0-15(VC)	Loose brown clay with oil sheen
						3	15-30	Brown soft clay with oil sheen, red sand at bottom 2 cm

NA= Not Applicable

Table 3-6. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
STP 10	2.74	3	NA	10	NA	1	0-10	Coarse reddish sand with some clay
STP 12	4.36	3	NA	5	0.91	1	0-10	Soft, loose brown clay with oil sheen and detritus
						2	15-30	Soft brown clay with heavy oil and detritus
						3	30-46	Black/brown silty sand
						4	76-91	Black, fibrous silt over brown clay, oily smell

NA= Not Applicable

Table 3-7. Description of Field Results for Slip C (SUS 1-8)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
SUS 1	6.40	2	12	4	1.60	1	0-21	Dark brown silty sand, some oil
						2	15-30	Soft, fibrous sandy silt, oil spots
						3	30-45	Soft, fibrous sandy silt (10 cm) over more oily material
						4	145-160	Light brown coarse sand
SUS 2	6.40	2	NA	4	1.26	1	0-20	Dark brown silty sand
						2	15-30	Soft, grainy, dark brown silty sand, oil spots
						3	30-45	Firmer silty sand with fibrous layer near bottom
						4	111-126	Coarse sand with some clay pockets
SUS 3	5.72	2	10	4	1.55	1	0-18.5	Oily, dark brown, soft silty sand
						2	15-30	Fibrous sand with woody material
						3	30-45	Fibrous sand atop pure sand, some oily spots
						4	140-155	Sand atop thick fibrous layer
SUS 4	5.97	2	NA	4	1.15	1	0-20	Dark brown sand, few fibers/oil spots
						2	15-30	Sandy silt mixed with oil, few fibers
						3	30-45	Oily, fibrous sand/silt; distinct layer of fibers at bottom
						4	100-115	Black sand with small pockets of fibers
SUS 5	5.79	2	17	5	0.54	1	0-15	Soft brown silt with some oil spots, few fibers
						2	15-23	Very oily sand/silt atop sand
						3	24-38	Dark brown sand
						4	39-54	Sand atop fibrous layer including large chunk of wood

NA= Not Applicable

Table 3-7. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
SUS 6	6.76	2	NA	4	1.30	1	0-18.5	Oily, black-gray sand
						2	15-30	Rust-brown sand with white specks, some sticks
						3	30-45	Sand with a few fibers
						4	115-130	Sand with a few fibers
SUS 7	7.62	3	17	9	0.78	1	0-5	Wood and plant detritus atop red sand
						2	15-30	Oily soft brown clay with detritus over red sand
						3	30-45	Reddish sand and wood detritus, oil smell
						4	63-78	Red sand, no oil
SUS 8	7.32	1	NA	NA	NA	None	0-10	Coarse sand; could only collect 1 replicate for benthos

NA= Not Applicable

Table 3-8. Description of Field Results for WLSSD and Miller/Coffee Creek Embayment (WLS 1-20)

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
WLS 1	2.29	1	10	4	2.04	1	0-15	Soft brown silt, slight oil odor
						2	15-30	Soft, fibrous silt with heavy oil
						3	30-45	Black oil and fibers (5 cm) over soft brown silt
						4	189-204	Uniform brownish-gray clay
WLS 2	2.49	2	11	5	1.82	1	0-15	Soft brown silt, some oil and fibrous material
						2	15-30	Uniform gray-brown clay, slightly oily
						3	30-45	Stiff, gray-brown clay
						4	167-182	Uniform dark brown clay
WLS 3	2.08	2	9	3	1.88	1	0-18.5	Gray-brown silt/clay mixture with fibers
						2	15-30	Sandy with very fine silt, few fibers
						3	30-45	Silty clay with some wood chunks
						4	173-188	Dark brown clay with plant detritus
WLS 4	2.34	2	8	4	1.21	1	0-20	Loose, brown silty clay, slight oil, little detritus
						2	15-30	Sand with little detritus, no oil, some stones
						3	30-45	Similar to 15-30 cm section
						4	105-120	Grayish-brown clay with a few stones
WLS 5	1.92	2	NA	3	1.50	1	0-18	Soft brown silty clay, some oil
						2	15-30	Brown silty clay, some oil; coal chunks and fibers at bottom of section
						3	30-45	Coal/sand/clay with abundant oil blooms
						4	135-150	Very fibrous, organic brown stratum with some larger wood chips

NA= Not Applicable

Table 3-8. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
WLS 6	6.80	2	6	4	2.50	1	0-19	Loose silty clay with black oil streaks
						2	15-30	Soft brown silt with oil sheen
						3	30-45	Same as 15-30 cm section
						4	235-250	Soft, gray clay with fibers
WLS 7	5.33	2	NA	4	0.5	1	0-20	Soft brown silt/clay with oil spots
						2	5-20	Soft silt with a lot of oil
						3	20-35	Loose silt/clay (5 cm) over oily sand
						4	35-50	Sand with oily coal chunks and small red clay pieces
WLS 8	3.28	2	5	4	1.05	1	0-20	Very oily silty clay with fibers
						2	15-30	Grayish-brown, stiff fibrous clay
						3	30-45	Stiff gray-brown clay with fewer fibers
						4	90-105	Peaty organic cattail-like detritus
WLS 9	7.92	2	NA	3	1.60	1	0-20	Soft brown silt/clay with oil at bottom 5 cm
						2	15-30	Heavy oil (5 cm) over fibrous clay with oil streaks
						3	30-45	Uniform, soft gray fibrous clay
						4	145-160	Uniform, stiff fibrous clay
WLS 10	1.98	2	NA	5	1.50	1	0-15	Brown soft silt over very oily layer (3 cm)
						2	15-30	Uniform clay/sand, no visible oil
						3	30-45	Uniform sandy clay, no visible oil
						4	135-150	Dry brownish sand, no fibers present

NA= Not Applicable

Table 3-8. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
WLS 11	10.52	2	NA	3	1.60	1	0-21	Soft, oily brownish-black silt
						2	15-30	Soft silty clay with some oil (10 cm) over heavy oil (5 cm)
						3	30-45	Black oily soft clay, few fibers, some coal pieces
						4	145-160	Sandy clay with a few oil spots and fibers
WLS 12	2.13	2	8	3	1.68	1	0-20	Very soft silt with black oil streaks
						2	15-30	Uniform, soft brown silty clay, no odor
						3	30-45	Mostly soft, black/oily silty clay
						4	153-168	Stiff, uniform brown clay
WLS 13	2.13	2	7	3	1.70	1	0-20	Dark clay/sand with oil spots, some fibers
						2	15-30	Soft brown clay (5 cm) over heavy oil
						3	30-45	Heavy oil (10 cm) over oil/wood chips
						4	155-170	Stiff heavy clay
WLS 14	2.44	2	10	3	1.55	1	0-15	Silty clay, some oil sheen and wood chips
						2	15-30	Uniform, stiff brown clay, no oil, some fibers
						3	30-45	Uniform, stiff brown clay, some fibers
						4	140-155	Brown clay, paper at bottom of section
WLS 15	2.59	3	NA	8	1.82	1	0-10	Sand/clay over black oil (few cm)
						2	15-30	Oily black sand with some silt
						3	30-45	Oily sand with some coal
						4	165-180	Clay/sand with some black oil

NA= Not Applicable

Table 3-8. Continued

Site Number	Water Depth (m)	# Cores per Benthos Rep.	# Cores for Toxicity	# Cores for Chemistry	Vibrocore Length (m)	Sections Collected (#)	Depth (cm)	Description
WLS 16	2.06	2	8	3	1.75	1	0-20	Soft brown silt/clay, some oil
						2	15-30	Soft silt/clay (10 cm) over black oil
						3	30-45	Heavy black oil (7 cm) over stiff brown clay
						4	160-175	Uniform, stiff brown clay with some fibers
WLS 17	2.06	3	NA	7	0.68	1	0-15	Soft brown silt/clay, slight oil sheen, some detritus
						2	15-30	Uniform, brown fibrous sand, no oil
						3	30-45	Uniform sand with wood chips, no oil
						4	50-65	Sandy brown clay with wood chips, no oil
WLS 18	2.21	2	NA	4	1.71	1	0-15	Soft silty clay (10 cm) atop oil
						2	15-30	Soft brown clay with reddish streaks
						3	30-45	Stiff brown clay with red and gray streaks
						4	156-171	Uniform, stiff brown clay with fibers
WLS 19	2.29	2	NA	3	1.96	1	0-20	Soft silty clay (10 cm) atop oil, little detritus
						2	15-30	Stiff brown fibrous clay with some pink clay
						3	30-45	Same as 15-30 cm section
						4	181-196	Very stiff brown clay with some wood chips
WLS 20								Too hard-bottomed to sample. Site appeared to have 5 cm of sediment on top of logs.

NA= Not Applicable

Table 3-9. Particle Size Distribution of all Sample Sites and Depth Profiles

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Percentages in different ranges Silt 53-2 µm	Clay 2-0 µm	Comments
DMIR 1	0-15	48.5	41.8	9.7	Average of analytical replicates
DMIR 2	0-15	22.6	58.8	18.6	Average of analytical replicates
DMIR 3	0-15	29.2	54.2	16.6	
DMIR 4	0-15	30.0	54.4	15.6	Average of analytical replicates
ERP 1	0-8	60.8	31.6	7.6	manually run
ERP 2	0-8	98.2	1.2	0.6	manually run, mostly sand
ERP 3	0-5	94.8	3.9	1.3	manually run, mostly sand
ERP 4	0-5	89.5	8.2	2.3	manually run, sand/fines
ERP 5	0-5	94.0	4.4	1.6	manually run, sand
HOB 1	0-5	67.4	24.4	8.2	
HOB 2	0-15	42.3	41.4	16.3	
HOB 3	0-15	45.1	37.6	17.3	
HOB 4	0-15	57.8	30.4	11.8	
HOB 5	0-15	49.9	36.6	13.5	
HOB 6	0-15	70.2	20.3	9.5	
HOB 7	0-15	52.8	35.4	11.8	
HOB 8	0-5	40.9	38.9	20.2	
HOB 9	0-5	27.7	36.2	36.1	Average of analytical replicates
HOB 10	0-10	89.1	7.2	3.6	Average of analytical replicates
HOB 11	0-15	61.9	27.9	10.2	
HOB 12	0-10	47.8	36.2	16.0	Average of analytical replicates
HOB 13	0-10	56.5	31.1	12.4	
HOB 14	0-15	48.8	38.9	12.3	
HOB 15	0-10	64.0	27.0	9.0	
HOB 2	15-30	40.5	43.0	16.5	
HOB 3	15-30	32.9	45.8	21.3	
HOB 4	15-30	50.4	34.4	15.2	
HOB 5	15-30	37.8	42.3	19.9	
HOB 6	15-30	96.1	3.2	0.7	coarse sand - manually run
HOB 7	15-30	73.5	18.5	8.1	
HOB 10	15-30	80.7	14.0	5.3	
HOB 11	10-25	17.0	24.7	58.3	red clay
HOB 14	15-30	16.3	38.0	45.7	red clay
HOB 15	15-30	76.4	17.3	6.3	Average of analytical replicates
HOB 2	30-45	41.9	41.6	16.5	
HOB 3	30-45	21.6	24.9	53.5	red clay
HOB 4	30-45	56.1	28.8	15.1	

Table 3-9. Continued

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Silt 53-2 µm	Clay 2-0 µm	Comments
			Percentages in different ranges		
HOB 5	30-45	51.6	34.9	13.5	
HOB 6	30-45	94.8	3.4	1.8	manually run, coarse sand
HOB 7	30-45	61.6	27.0	11.4	
HOB 10	30-45	71.7	20.5	7.9	
HOB 11	25-40	22.3	27.4	50.3	red clay
HOB 14	30-45	32.4	52.0	15.5	lots of wood
HOB 15	30-45	78.9	14.8	6.2	Average of analytical replicates
KMB 1	0-8	67.5	27.0	5.4	
KMB 2	0-12	44.3	46.6	9.1	
KMB 3	0-15	38.5	46.2	15.3	wood fiber
KMB 4	0-15	28.5	44.6	26.9	Average of analytical replicates
KMB 5	0-15	9.7	54.1	36.2	Average of analytical replicates
MLH 1	0-12	47.8	41.4	10.9	Average of analytical replicates
MLH 2	0-20	87.7	9.9	2.4	Average of analytical replicates
MLH 3	0-15	62.7	30.2	7.1	
MLH 4	0-20	34.5	47.8	17.7	
MLH 5	0-17	50.6	36.2	13.3	
MLH 6	0-21	92.2	5.8	2.0	
MLH 7	0-17	52.8	34.8	12.4	Average of analytical replicates
MLH 8	0-15.5	60.7	29.1	10.2	
MLH 9	0-20	45.2	40.6	14.3	
MLH 10	0-20	40.5	45.7	13.8	
MLH 1	25-40	48.1	42.2	9.6	
MLH 2	80-95	57.4	38.6	4.0	%T (transmittance) high
MLH 3	37-52	-	-	-	Insufficiant sample for analysis
MLH 4	30-50	86.1	10.7	3.2	
MLH 5	32-47	60.6	32.0	7.5	
MLH 6	25-40	95.7	3.3	1.0	manually run
MLH 7	72-87	89.8	8.4	1.8	
MLH 8	60-76	97.6	1.8	0.6	manually run
MLH 9	52-79	69.6	26.5	3.9	
MLH 10	75-95	41.3	44.3	14.4	Average of analytical replicates
MNS 1	0-10	48.2	40.0	11.8	
MNS 2	0-12	59.4	33.3	7.3	Average of analytical replicates
MNS 3	0-15	54.1	35.8	10.1	
MNS 4	0-15	61.4	28.7	9.8	Average of analytical replicates

Table 3-9. Continued

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Percentages in different ranges		
			Silt 53-2 µm	Clay 2-0 µm	Comments
MNS 4	0-15(VC)	93.3	5.0	1.7	Average of analytical replicates
MNS 5	0-10	84.8	11.8	3.4	sand
MNS 5	5-20 (VC)	92.6	5.1	2.2	sand
MNS 1	9-24	52.4	37.9	9.7	Average of analytical replicates
MNS 2	15-30	59.0	33.1	7.9	
MNS 3	15-30	51.3	36.7	12.0	
MNS 4	15-30	94.7	4.3	0.9	manually run, sand and large pebble
MNS 5	20-35	96.9	2.0	1.1	required gross sieving
MNS 1	24-39	56.1	34.8	9.0	
MNS 2	95-125	62.3	31.5	6.2	
MNS 3	30-45	78.1	16.2	5.7	
MNS 4	30-45	95.3	3.6	1.1	sandy
MNS 5	35-50	94.6	3.8	1.6	required gross sieving
MNS 1	39-54	58.8	33.0	8.2	
MNS 2	145-160	64.2	29.4	6.4	
MNS 3	45-60	86.9	10.4	2.7	
STP 1	0-15	76.9	17.0	6.2	Average of analytical replicates
STP 2	0-15	85.8	10.9	3.2	Average of analytical replicates
STP 3	0-10	70.3	22.7	7.1	
STP 4	0-15	50.8	40.1	9.1	
STP 5	0-15	31.7	51.7	16.6	
STP 6	0-15	31.8	56.6	11.5	
STP 7	0-15	30.9	57.0	12.1	
STP 8	0-15	20.0	59.4	20.5	
STP 10	0-10	61.7	28.1	10.2	
STP 12	0-10	60.5	30.2	9.3	
STP 1	15-30	49.3	41.0	9.7	
STP 2	10-25	17.2	57.9	24.9	Average of analytical replicates
STP 3	15-30	85.1	11.7	3.1	Average of analytical replicates
STP 4	15-30	32.4	56.4	11.2	Average of analytical replicates
STP 6	7-23	37.6	51.4	10.9	Average of analytical replicates
STP 7	5-23	47.1	43.1	9.7	
STP 8	15-30	38.8	47.2	13.9	
STP 12	15-30	42.8	42.2	14.9	
STP 1	30-45	79.9	14.3	5.8	
STP 3	30-45	88.3	9.3	2.5	Average of analytical replicates
STP 4	30-45	21.8	66.3	11.9	

Table 3-9. Continued

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Silt 53-2 µm	Clay 2-0 µm	Comments
			Percentages in different ranges		
STP 6	23-38	29.3	55.6	15.2	
STP 12	30-46	39.7	43.8	16.6	Average of analytical replicates
STP 12	76-91	54.6	35.2	10.1	Average of analytical replicates
SUS 1	0-15	71.8	22.3	5.9	
SUS 2	0-15	70.6	22.6	6.8	
SUS 3	0-15	72.8	21.2	5.9	
SUS 4	0-15	67.5	26.1	6.4	
SUS 5	0-15	80.9	14.7	4.4	
SUS 6	0-15	-	-	-	Insufficiant sample for analysis
SUS 7	0-5	85.9	10.9	3.2	Average of analytical replicates
SUS 1	15-30	45.9	44.8	9.2	Average of analytical replicates
SUS 2	15-30	67.4	28.8	3.8	
SUS 3	15-30	83.4	13.5	3.1	
SUS 4	15-30	84.4	12.6	3.0	
SUS 5	15-23	98.2	1.4	0.4	
SUS 6	15-30	98.1	1.5	0.4	manually run
SUS 7	15-30	91.4	7.2	1.4	manually run
SUS 1	30-45	69.6	25.5	4.8	
SUS 2	30-45	71.6	23.6	4.8	
SUS 3	30-45	87.8	9.8	2.3	
SUS 4	30-45	77.9	18.6	3.5	
SUS 5	24-38	96.3	2.8	0.9	manually run, slag chunk and sand
SUS 6	30-45	98.1	1.5	0.4	manually run
SUS 7	30-45	99.0	0.8	0.2	manually run
SUS 1	145-160	97.7	1.8	0.5	manually run
SUS 2	111-126	90.9	7.4	1.8	Average of analytical replicates
SUS 3	140-155	79.8	16.9	3.3	
SUS 4	100-115	92.5	6.4	1.2	Average of analytical replicates
SUS 5	39-54	93.7	5.2	1.1	slag chunk in subsample
SUS 6	115-130	97.6	2.0	0.4	
SUS 7	63-78	99.6	0.3	0.1	manually run
WLS 1	0-15	28.2	58.9	12.9	Average of analytical replicates
WLS 2	0-15	46.9	41.5	11.6	Average of analytical replicates
WLS 3	0-17	49.7	38.8	11.5	
WLS 4	0-20	32.9	51.5	15.6	
WLS 5	0-18	29.3	53.4	17.4	Average of analytical replicates
WLS 6	0-15	15.7	62.5	21.8	

Table 3-9. Continued

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Percentages in different ranges Silt 53-2 µm	Clay 2-0 µm	Comments
WLS 7	0-15	19.1	60.1	20.8	
WLS 8	0-15	25.5	55.8	18.7	
WLS 9	0-20	16.6	64.3	19.0	
WLS 10	0-15	40.9	46.2	12.9	
WLS 11	0-20	18.2	61.4	20.4	
WLS 12	0-19	32.4	51.6	16.1	
WLS 13	0-18	37.3	45.9	16.7	
WLS 14	0-15	30.0	48.8	21.1	
WLS 15	0-5	71.0	22.1	6.9	
WLS 16	0-18	36.9	48.5	14.6	
WLS 17	0-5	82.3	14.2	3.5	Average of analytical replicates
WLS 18	0-15	50.4	38.6	11.1	Average of analytical replicates
WLS 19	0-20	31.8	49.9	18.3	
WLS 1	15-30	35.4	51.2	13.5	
WLS 2	15-30	26.6	56.2	17.2	Average of analytical replicates
WLS 3	15-30	62.2	30.9	7.0	
WLS 4	15-30	96.1	2.8	1.1	
WLS 5	15-30	38.5	45.5	16.0	sand, manually run
WLS 6	15-30	46.1	40.9	13.0	
WLS 7	5-20	28.0	56.0	16.0	
WLS 8	15-30	24.7	60.4	14.9	
WLS 9	15-30	38.4	47.3	14.3	wood fiber
WLS 10	15-30	69.6	20.2	10.3	
WLS 11	15-30	20.4	62.2	17.3	sandy clay
WLS 12	15-30	15.6	61.6	22.9	
WLS 13	15-30	26.7	57.7	15.6	
WLS 14	15-30	55.8	36.1	8.1	
WLS 15	15-30	80.6	15.2	4.2	
WLS 16	15-30	12.8	65.7	21.5	
WLS 17	15-30	67.7	28.1	4.2	
WLS 18	15-30	43.0	43.3	13.7	Average of analytical replicates
WLS 19	15-30	31.4	50.3	18.3	
WLS 1	30-45	34.0	50.4	15.6	
WLS 2	30-45	20.5	61.0	18.5	
WLS 3	30-45	16.1	63.6	20.3	
WLS 4	30-45	97.7	1.6	0.7	manually run
WLS 5	30-45	78.9	16.4	4.8	Average of analytical replicates

Table 3-9. Continued

Site Code	Core Depth (cm)	Sand & Gravel >53 µm	Silt 53-2 µm	Clay 2-0 µm	Comments
			Percentages in different ranges		
WLS 6	30-45	34.6	49.5	15.6	Average of analytical replicates
WLS 7	20-35	78.5	16.6	5.0	
WLS 8	30-45	25.2	61.9	12.9	wood fiber
WLS 9	30-45	31.5	51.8	16.6	
WLS 10	30-45	68.9	21.4	9.7	
WLS 11	30-45	20.0	63.5	16.5	large chunk of wood in sample
WLS 12	30-45	12.4	65.9	21.7	
WLS 13	30-45	42.7	41.7	15.6	
WLS 14	30-45	31.9	55.2	12.9	
WLS 15	30-45	71.7	22.5	5.8	1 large pebble with finer material
WLS 16	30-45	17.9	61.4	20.7	Average of analytical replicates
WLS 17	30-45	65.0	30.8	4.2	
WLS 18	30-45	36.4	41.9	21.7	
WLS 19	30-45	46.7	42.0	11.3	Average of analytical replicates
WLS 1	189-204	20.4	66.7	12.9	
WLS 2	167-182	22.2	63.7	14.1	
WLS 3	173-188	55.2	39.8	5.0	
WLS 4	105-120	15.1	66.5	18.4	
WLS 5	135-150	43.5	48.0	8.5	Average of analytical replicates
WLS 6	235-250	65.9	29.6	4.5	
WLS 7	35-50	89.2	7.1	3.7	sandy
WLS 8	90-105	68.6	25.6	5.8	pulpy organics, manually run
WLS 9	145-160	22.8	58.7	18.5	
WLS 10	135-150	81.1	14.9	4.1	
WLS 11	145-160	80.1	16.5	3.4	
WLS 12	153-168	25.1	61.4	13.5	
WLS 13	155-170	31.4	55.3	13.3	
WLS 14	140-155	28.3	58.6	13.2	
WLS 15	165-180	48.5	40.7	10.8	
WLS 16	160-175	34.8	52.8	12.4	
WLS 17	50-65	75.6	21.1	3.3	
WLS 18	156-171	41.8	47.0	11.3	Average of analytical replicates
WLS 19	181-196	31.7	53.1	15.2	Average of analytical replicates

Table 3-10. TOC Results for all Sample Sites and Depth Profiles

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
DMIR 1	0-15	2.5			
DMIR 2	0-15	2.3	0.02	0.93	AR
DMIR 3	0-15	2.9			
DMIR 4	0-15	2.6			
ERP 1	0-8	2.9			
ERP 2	0-8	0.28			
ERP 3	0-5	2.9			
ERP 4	0-5	1.6	0.06	3.6	AR/ER
ERP 5	0-5	0.46			
HOB 1	0-5	1.3			
HOB 2	0-15	3.8			
HOB 3	0-15	3.5			
HOB 4	0-15	2.5	0.21	8.1	ER
HOB 5	0-15	3.2			
HOB 6	0-15	2.4	0.18	7.7	AR
HOB 7	0-15	3.0			
HOB 8	0-5	2.8			
HOB 9	0-5	0.90			
HOB 10	0-10	1.8			
HOB 11	0-15	3.0			
HOB 12	0-10	2.2			
HOB 13	0-10	3.2			
HOB 14	0-15	3.9	0.19	4.8	AR/ER
HOB 15	0-10	5.2	0.49	9.5	AR
HOB 2	15-30	3.7			
HOB 3	15-30	3.0			
HOB 4	15-30	3.3			
HOB 5	15-30	2.6			
HOB 6	15-30	0.66			
HOB 7	15-30	2.7			
HOB 10	15-30	3.2			
HOB 11	10-25	0.32			
HOB 14	15-30	0.92	0.02	2.3	ER
HOB 15	15-30	3.7	0.01	0.19	AR

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
HOB 2	30-45	4.3			
HOB 3	30-45	0.67			
HOB 4	30-45	4.1			
HOB 5	30-45	2.2			
HOB 6	30-45	0.32			
HOB 7	30-45	2.9			
HOB 10	30-45	1.9			
HOB 11	25-40	0.34			
HOB 14	30-45	4.7	0.06	1.4	ER
HOB 15	30-45	4.4	0.83	19	AR
KMB 1	0-8	2.2			
KMB 2	0-12	1.7			
KMB 3	0-15	3.1			
KMB 4	0-15	2.2	0.07	3.2	AR
KMB 5	0-15	2.8			
MLH 1	0-12	5.0	0.01	0.14	AR
MLH 2	0-20	7.1			
MLH 3	0-15	12			
MLH 4	0-20	6.6			
MLH 5	0-17	6.5	0.10	1.5	AR
MLH 6	0-21	0.89			
MLH 7	0-17	3.8			
MLH 8	0-15.5	4.8			
MLH 9	0-20	6.3			
MLH 10	0-20	3.4	0.09	2.7	AR/ER
MLH 1	25-40	2.0			
MLH 2	80-95	19	0.40	2.1	AR
MLH 3	37-52	15	1.9	13	AR
MLH 4	30-50	2.4			
MLH 5	32-47	2.1			
MLH 6	25-40	2.4			
MLH 7	72-87	1.3	0.19	15	ER
MLH 8	60-76	0.18			
MLH 9	52-79	15	0.69	4.6	AR
MLH 10	75-95	4.1			

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
MNS 1	0-10	4.0	0.01	0.35	ER
MNS 2	0-12	4.8			
MNS 3	0-15	3.2			
MNS 4	0-15	3.5			
MNS 4	0-15(VC)	2.6			
MNS 5	0-10	2.4	0.01	0.58	AR
MNS 5	5-20 (VC)	1.6			
MNS 1	9-24	3.4			
MNS 2	15-30	3.8			
MNS 3	15-30	4.6			
MNS 4	15-30	1.9			
MNS 5	20-35	0.67	0.09	14	AR
MNS 1	24-39	4.2	0.02	0.50	ER
MNS 2	95-125	6.7			
MNS 3	30-45	4.0	0.28	6.9	AR
MNS 4	30-45	2.2	0.16	7.3	ER
MNS 5	35-50	2.9			
MNS 1	39-54	4.0			
MNS 2	145-160	4.6			
MNS 3	45-60	4.1	0.59	14	AR
STP 1	0-15	3.0			
STP 2	0-15	3.4			
STP 3	0-10	3.4			
STP 4	0-15	3.6			
STP 5	0-15	4.1			
STP 6	0-15	3.4			
STP 7	0-15	3.2			
STP 8	0-15	5.0			
STP 10	0-10	3.4	0.16	4.8	ER
STP 12	0-10	4.1			
STP 1	15-30	4.0	0.25	6.3	AR
STP 2	10-25	4.5			
STP 3	15-30	3.9			
STP 4	15-30	3.4			
STP 6	7-23	3.2			

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
STP 7	5-23	3.2			
STP 8	15-30	5.0			
STP 12	15-30	4.7			
STP 1	30-45	2.3	0.13	5.9	AR/ER
STP 3	30-45	2.0			
STP 3	30-45	1.8	0.03	1.6	AR
STP 4	30-45	4.6			
STP 6	23-38	3.6			
STP 12	30-46	3.7			
STP 12	76-91	6.4			
SUS 1	0-15	4.7	0.05	1.1	AR
SUS 2	0-15	3.5			
SUS 3	0-15	4.9			
SUS 4	0-15	4.3			
SUS 5	0-15	2.3			
SUS 6	0-15	1.9			
SUS 7	0-5	2.7	0.11	4.0	ER
SUS 1	15-30	19	0.91	4.9	AR
SUS 2	15-30	19	0.74	3.9	AR
SUS 3	15-30	4.8			
SUS 4	15-30	2.8			
SUS 5	15-23	0.83			
SUS 6	15-30	0.33			
SUS 7	15-30	3.0			
SUS 1	30-45	15	0.08	0.58	AR
SUS 2	30-45	11			
SUS 3	30-45	3.6	0.01	0.40	ER
SUS 4	30-45	4.3			
SUS 5	24-38	0.80			
SUS 6	30-45	0.28			
SUS 7	30-45	1.4			

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
SUS 1	145-160	1.4			
SUS 2	111-126	2.7			
SUS 3	140-155	3.1			
SUS 4	100-115	3.2	0.60	19	AR
SUS 5	39-54	2.4			
SUS 6	115-130	1.1	0.07	6.7	ER
SUS 7	63-78	0.29			
WLS 1	0-15	2.9			
WLS 2	0-15	2.3			
WLS 3	0-17	3.1			
WLS 4	0-20	3.0			
WLS 5	0-18	4.9	0.80	16	AR/ER
WLS 6	0-15	3.7			
WLS 7	0-15	3.5			
WLS 8	0-15	4.5			
WLS 9	0-20	3.8			
WLS 10	0-15	1.7			
WLS 11	0-20	3.6			
WLS 12	0-19	4.9	0.05	1.0	AR
WLS 13	0-18	4.7			
WLS 14	0-15	5.6			
WLS 15	0-5	2.6	0.83	32	AR/ER
WLS 16	0-18	4.7			
WLS 17	0-5	2.8	0.11	4.1	AR
WLS 18	0-15	2.7			
WLS 19	0-20	4.4			
WLS 1	15-30	3.3			
WLS 2	15-30	1.0			
WLS 3	15-30	3.5			
WLS 4	15-30	1.1			
WLS 5	15-30	8.7	0.93	11	AR
WLS 6	15-30	2.8			
WLS 7	5-20	3.7	0.09	2.5	AR/ER
WLS 8	15-30	3.9			

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
WLS 9	15-30	2.4			
WLS 10	15-30	2.6			
WLS 11	15-30	4.2			
WLS 12	15-30	3.5			
WLS 13	15-30	4.3	0.02	0.49	AR
WLS 14	15-30	2.3			
WLS 15	15-30	1.8			
WLS 16	15-30	3.7			
WLS 17	15-30	3.0	0.34	11	ER
WLS 18	15-30	1.9			
WLS 19	15-30	2.7			
WLS 1	30-45	3.3			
WLS 2	30-45	1.0			
WLS 3	30-45	4.5			
WLS 4	30-45	0.76			
WLS 5	30-45	27	1.0	3.7	AR
WLS 6	30-45	3.6			
WLS 7	20-35	1.4			
WLS 8	30-45	5.8	0.06	0.98	ER
WLS 9	30-45	3.1			
WLS 10	30-45	0.79			
WLS 11	30-45	3.5			
WLS 12	30-45	5.0			
WLS 13	30-45	6.8			
WLS 14	30-45	3.5	0.02	0.61	AR
WLS 15	30-45	3.9			
WLS 16	30-45	6.9	0.08	1.1	AR
WLS 17	30-45	2.8			
WLS 18	30-45	1.5	0.18	12	ER
WLS 19	30-45	2.7			

AR = Analytical replicate
ER = Extraction replicate

Table 3-10. Continued

Site Code	Core Depth (cm)	% Organic Carbon	% Std Dev	% RSD	Replicate Type
WLS 1	189-204	3.7			
WLS 2	167-182	5.2			
WLS 3	173-188	6.1			
WLS 4	105-120	4.3			
WLS 5	135-150	17	0.24	1.4	AR
WLS 6	235-250	2.2	0.22	9.9	ER
WLS 7	35-50	1.6			
WLS 8	90-105	27	0.06	0.24	AR
WLS 9	145-160	3.1			
WLS 10	135-150	0.38			
WLS 11	145-160	1.7			
WLS 12	153-168	4.4			
WLS 13	155-170	3.4			
WLS 14	140-155	2.4			
WLS 15	165-180	2.6			
WLS 16	160-175	4.6	0.06	1.4	ER
WLS 17	50-65	3.3			
WLS 18	156-171	1.7			
WLS 19	181-196	1.8			

AR = Analytical replicate
ER = Extraction replicate

Table 3-11. Ammonia Results for Selected Sites and Depth Profiles

Site Code	Core Depth (cm)	Replicate Type	Sediment Ammonia Conc.* (mg/kg) (dry wt.)
ERP 1	0-8		32.8
ERP 2	0-8		12.3
ERP 3	0-5		12.2
ERP 4	0-5	ER	17.4
ERP 5	0-5		3.30
KMB 1	0-8		11.1
KMB 2	0-12		12.1
KMB 3	0-15	ER	57.1
KMB 4	0-15		**119**
KMB 5	0-15		**178**
MNS 1	0-10		**116**
MNS 2	0-12		**138**
MNS 3	0-15		45.1
MNS 4	0-15	ER	23.1
MNS 5	0-10		10.2
STP 1	0-15		43.3
STP 2	0-15		8.32
STP 3	0-10		96.9
STP 4	0-15		29.2
STP 5	0-15		55.5
STP 6	0-15	ER	36.3
STP 7	0-15		29.4
STP 8	0-15		68.5
STP 10	0-10		15.1
STP 12	0-10		91.5
SUS 1	0-15		40.7
SUS 2	0-15		90.4
SUS 3	0-15		49.6
SUS 4	0-15		38.9
SUS 5	0-15		27.5
SUS 6	0-15		27.4
SUS 7	0-5		35.1
WLS 1	0-15		89.7
WLS 2	0-15		33.6
WLS 3	0-17		80.2
WLS 4	0-20		72.3
WLS 5	0-18		23.8
WLS 6	0-15		**119**
WLS 7	0-15		79.9
WLS 8	0-15		84.4

* Values in bold exceed the Ontario Open Water Disposal Guidelines of 100 mg/kg ammonia.
ER = Extraction replicate

Table 3-11. Continued

Site Code	Core Depth (cm)	Replicate Type	Sediment Ammonia Conc.* (mg/kg) (dry wt.)
WLS 9	0-20	ER	**123**
WLS 10	0-15		15.5
WLS 11	0-20		**219**
WLS 12	0-19		**150**
WLS 13	0-18		**101**
WLS 14	0-15		63.2
WLS 15	0-5		24.9
WLS 16	0-18		**101**
WLS 17	0-5	ER	19.5
WLS 18	0-15		21.9
WLS 19	0-20		65.8
WLS 1	189-204		70.4
WLS 2	167-182		**176**
WLS 3	173-188		25.9
WLS 4	105-120		**125**
WLS 5	135-150		30.5
WLS 6	235-250		6.69
WLS 7	35-50		ND
WLS 8	90-105		**183**
WLS 9	145-160		**164**
WLS 10	135-150		32.3
WLS 11	145-160		30.6
WLS 12	153-168		**104**
WLS 13	155-170		41.9
WLS 14	140-155		97.1
WLS 15	165-180		**101**
WLS 16	160-175	ER	68.3
WLS 17	50-65		52.1
WLS 18	156-171		81.3
WLS 19	181-196		**102**

*Values in bold exceed the Ontario Open Water Disposal Guidelines of 100 mg/kg ammonia.
ER = Extraction replicate

Table 3-12. Total Arsenic and Lead Results for Howard's Bay Samples

Site Code	Core Depth (cm)	Replicate Type	Total As Conc. (mg/kg) (dry wt.)	Total Pb Conc. (mg/kg) (dry wt.)
HOB 1	0-5	ER	**12.0**	20.1
HOB 1	0-5 (Vibr)		**7.82**	9.08
HOB 2	0-15		**23.7**	**111**
HOB 3	0-15		**27.3**	**92.5**
HOB 4	0-15		**16.7**	**78.5**
HOB 5	0-15		**9.59**	**89.3**
HOB 6	0-15		**12.9**	28.1
HOB 7	0-15		**20.5**	**163**
HOB 8	0-5		**24.3**	**113**
HOB 9	0-5		**26.6**	**34.1**
HOB 10	0-10		**8.21**	**94.5**
HOB 11	0-15	ER	**17.7**	**215**
HOB 12	0-10		**27.5**	**132**
HOB 13	0-10		**19.3**	**269**
HOB 14	0-15		**23.1**	**104**
HOB 15	0-10		**14.2**	**194**
HOB 1	5-20		**11.6**	**1500**
HOB 2	15-30		**22.6**	**99.5**
HOB 3	15-30		**13.0**	**73.1**
HOB 4	15-30		**22.3**	**125**
HOB 5	15-30		**27.0**	**67.3**
HOB 6	15-30	ER	1.40	8.17
HOB 7	15-30		**12.9**	**123**
HOB 10	15-30		**10.3**	**76.2**
HOB 11	10-25		**22.1**	**37.0**
HOB 14	15-30		**35.2**	**67.7**
HOB 15	15-30		5.35	**132**
HOB 2	30-45		**13.6**	**182**
HOB 3	30-45		**18.8**	**42.0**
HOB 4	30-45		**10.6**	**1350**
HOB 5	30-45	ER	**7.62**	**79.6**
HOB 6	30-45		0.00	**10.9**
HOB 7	30-45		**7.19**	**140**
HOB 10	30-45		3.34	**61.2**
HOB 11	25-40		**17.4**	**48.5**
HOB 14	30-45		**17.7**	**215**
HOB 15	30-45		5.11	**120**

Vibr = Sample collected with a vibrocorer
ER = Extraction replicate
Bold values exceed the OMOEE LEL values.
Bold grey cell values exceed the OMOEE SEL values.

Table 3-13. AVS Results for Selected Sites

Site Code	Replicate Type	Core Depth (cm)	Sulfide Conc. (umol/g) (dry wt.)	Mean Sulfide Conc. (umol/g)	Standard Deviation	%RSD
DMIR 1		0-15	1.02			
DMIR 2		0-15	7.49			
DMIR 2	ER	0-15	7.24	7.36	0.17	2.3
DMIR 3		0-15	3.33			
DMIR 4		0-15	2.62			
ERP 1		0-8	3.23			
ERP 2		0-8	0.32			
ERP 3		0-5	0.86			
ERP 4		0-5	1.11			
ERP 5		0-5	**0.13**			
HOB 1		0-5	1.82			
HOB 1		0-5 (Vibr)	0.29			
HOB 2		0-15	3.52			
HOB 3		0-15	3.33			
HOB 4		0-15	7.96			
HOB 5		0-15	6.15			
HOB 6		0-15	1.26			
HOB 7		0-15	2.49			
HOB 8		0-5	0.36			
HOB 9		0-5	**0.10**			
HOB 10		0-10	3.80			
HOB 10	ER	0-10	3.55	3.67	0.17	4.7
HOB 11		0-15	3.12			
HOB 12		0-10	3.92			
HOB 13		0-10	3.85			
HOB 14		0-15	3.01			
HOB 14	ER	0-15	3.05	3.03	0.03	0.80
HOB 15		0-10	21.7			
HOB 1		5-20	<LOD			
HOB 2		15-30	5.26			
HOB 3		15-30	0.37			
HOB 4		15-30	**0.13**			
HOB 5		15-30	**0.18**			
HOB 6		15-30	<LOD			
HOB 7		15-30	0.27			
HOB 7	ER	15-30	**0.12**			

Vibr = Sample collected with the vibrocorer
<LOD = Sulfide level below Limit of Detection
Bold Values: Sulfide level below Limit of Quantification
ER = Extraction Replicate

Table 3-13. Continued

Site Code	Replicate Type	Core Depth (cm)	Sulfide Conc. (umol/g) (dry wt.)	Mean Sulfide Conc. (umol/g)	Standard Deviation	%RSD
HOB 10		15-30	**0.19**			
HOB 10	ER	15-30	0.34			
HOB 11		10-25	<LOD			
HOB 14		15-30	<LOD			
HOB 15		15-30	11.80			
HOB 2		30-45	2.76			
HOB 3		30-45	<LOD			
HOB 4		30-45	**0.12**			
HOB 5		30-45	**0.11**			
HOB 6		30-45	<LOD			
HOB 7		30-45	**0.08**			
HOB 10		30-45	<LOD			
HOB 11		25-40	<LOD			
HOB 14		30-45	<LOD			
HOB 15		30-45	10.94			
KMB 1		0-8	0.44			
KMB 2		0-12	1.22			
KMB 3		0-15	4.50			
KMB 3	ER	0-15	4.62	4.56	0.08	1.8
KMB 4		0-15	19.3			
KMB 5		0-15	18.6			
MLH 1		0-12	1.99			
MLH 1	ER	0-12	2.03	2.01	0.03	1.4
MLH 2		0-20	2.70			
MLH 3		0-15	2.87			
MLH 4		0-20	3.86			
MLH 5		0-17	2.10			
MLH 5	ER	0-17	1.93	2.02	0.12	6.2
MLH 6		0-21	**0.13**			
MLH 7		0-17	2.45			
MLH 8		0-15.5	4.10			
MLH 9		0-20	3.12			
MLH 9	ER	0-20	3.97	3.55	0.60	16
MLH 10		0-20	4.41			
MLH 1		25-40	0.28			
MLH 2		80-95	1.83			

<LOD = Sulfide level below Limit of Detection
Bold Values: Sulfide level below Limit of Quantification
ER = Extraction Replicate

Table 3-13. Continued

Site Code	Replicate Type	Core Depth (cm)	Sulfide Conc. (umol/g) (dry wt.)	Mean Sulfide Conc. (umol/g)	Standard Deviation	%RSD
MLH 3		37-52	<LOD			
MLH 4		30-50	**0.08**			
MLH 5		32-47	<LOD			
MLH 6		25-40	<LOD			
MLH 7		72-87	<LOD			
MLH 7	ER	72-87	<LOD			
MLH 8		60-76	<LOD			
MLH 9		52-79	<LOD			
MLH 10		75-95	**0.18**			

<LOD = Sulfide level below Limit of Detection
Bold Values: Sulfide level below Limit of Quantification
ER = Extraction Replicate

Table 3-14. SEM Results for Selected Sites

Site Code	Core Depth (cm)	Replicate Type	Cadmium Conc. (mg/kg) (dry wt.)	Copper Conc. (mg/kg) (dry wt.)	Nickel Conc. (mg/kg) (dry wt.)	Lead Conc. (mg/kg) (dry wt.)	Zinc Conc. (mg/kg) (dry wt.)
DMIR 1	0-15		0.845	13.0	7.25	20.2	64.6
DMIR 2	0-15	ER	0.822	8.67	4.56	19.7	71.5
DMIR 3	0-15		0.890	15.3	8.23	19.0	77.5
DMIR 4	0-15		0.794	15.0	6.35	14.0	62.4
ERP 1	0-8		0.741	10.8	7.00	15.8	73.3
ERP 2	0-8		0.113	1.50	1.52	2.29	11.2
ERP 3	0-5		0.194	2.77	4.13	4.65	20.9
ERP 4	0-5		0.310	2.74	5.14	4.93	22.9
ERP 5	0-5		0.144	2.31	1.88	6.14	18.3
HOB 1	0-5		0.819	14.8	7.29	20.7	50.8
HOB 1	0-5 (VC)		0.711	21.2	4.51	8.22	20.6
HOB 2	0-15		1.23	29.9	12.8	111	145
HOB 3	0-15		1.24	28.2	11.4	83.2	127
HOB 4	0-15		1.05	28.6	11.8	177	119
HOB 5	0-15		1.32	34.6	11.9	139	155
HOB 6	0-15		0.462	11.4	6.42	47.5	33.5
HOB 7	0-15		1.21	39.3	13.5	142	145
HOB 8	0-5		1.17	194	14.1	97.9	151
HOB 9	0-5		0.838	27.4	9.92	21.0	37.3
HOB 10	0-10	ER	0.528	13.3	6.19	50.7	55.1
HOB 11	0-15		1.08	40.1	12.2	277	151
HOB 12	0-10		1.32	29.1	13.8	161	165
HOB 13	0-10		1.51	65.3	16.6	253	177
HOB 14	0-15	ER	1.01	26.7	12.3	108	112
HOB 15	0-10		1.34	29.4	10.0	172	184
HOB 1	5-20		0.933	3.10	2.24	<LOD	4.65
HOB 2	15-30		1.54	36.9	17.7	105	169
HOB 3	15-30		1.55	42.6	14.2	100	172
HOB 4	15-30		1.54	44.5	14.2	139	190
HOB 5	15-30		1.46	43.5	12.1	84.3	145
HOB 6	15-30		0.201	1.51	2.18	0.75	6.03
HOB 7	15-30	ER	0.688	18.9	4.14	111	82.5
HOB 10	15-30	ER	0.606	18.8	7.19	69.4	97.1
HOB 11	10-25		0.825	22.6	6.32	14.3	21.9
HOB 14	15-30		1.08	23.9	7.21	92.4	75.7
HOB 15	15-30		0.963	23.5	8.12	154	163

<LOD = Value obtained is lower then detection limit
ER = Values reported are the mean of extraction replicates

Table 3-14. Continued

Site Code	Core Depth (cm)	Replicate Type	Cadmium Conc. (mg/kg) (dry wt.)	Copper Conc. (mg/kg) (dry wt.)	Nickel Conc. (mg/kg) (dry wt.)	Lead Conc. (mg/kg) (dry wt.)	Zinc Conc. (mg/kg) (dry wt.)
HOB 2	30-45		1.35	38.4	13.0	116	175
HOB 3	30-45		0.962	27.0	9.84	19.1	44.5
HOB 4	30-45		1.18	35.7	9.32	129	159
HOB 5	30-45		1.13	27.8	8.82	63.1	108
HOB 6	30-45		<LOD	1.61	1.55	4.71	4.36
HOB 7	30-45		1.03	36.1	12.1	171	142
HOB 10	30-45		0.676	21.7	7.18	59.3	78.0
HOB 11	25-40		0.802	24.3	11.3	17.7	30.1
HOB 14	30-45		0.822	29.5	11.7	234	132
HOB 15	30-45		0.894	21.5	8.22	132	142
KMB 1	0-8		0.419	6.92	6.81	5.47	34.0
KMB 2	0-12		0.39	3.98	4.09	6.80	33.6
KMB 3	0-15	ER	1.03	14.3	8.96	31.7	119
KMB 4	0-15		0.973	17.6	10.6	29.6	102
KMB 5	0-15		1.11	21.3	14.3	36.9	139
MLH 1	0-12		1.39	15.4	8.52	30.0	78.4
MLH 2	0-20		0.696	8.49	4.15	6.58	28.5
MLH 3	0-15		0.975	13.7	4.73	26.4	82.0
MLH 4	0-20		1.46	20.9	9.02	51.1	178
MLH 5	0-17	ER	1.29	19.0	8.04	49.3	161
MLH 6	0-21		0.155	3.93	2.60	3.87	14.8
MLH 7	0-17		1.05	14.6	7.34	38.0	125
MLH 8	0-15.5		0.949	15.9	9.08	30.3	115
MLH 9	0-20		1.38	17.2	7.43	46.4	167
MLH 10	0-20		0.812	9.07	6.99	17.5	81.6
MLH 1	25-40		0.548	8.71	5.69	3.26	23.6
MLH 2	80-95		0.545	9.91	3.43	9.69	34.7
MLH 3	37-52		1.14	33.3	7.76	22.8	60.4
MLH 4	30-50		0.246	5.42	4.95	1.87	18.2
MLH 5	32-47		0.351	6.50	5.24	1.52	19.9
MLH 6	25-40		0.175	3.51	3.52	1.40	10.8
MLH 7	72-87	ER	0.250	5.18	4.01	1.51	12.7
MLH 8	60-76		<LOD	4.38	3.51	0.580	8.23
MLH 9	52-79		0.434	11.3	8.71	<LOD	32.5
MLH 10	75-95		0.883	17.1	7.97	58.1	84.4

<LOD = Value obtained is lower then detection limit
ER = Values reported are the mean of extraction replicates

Table 3-15. SEM/AVS Ratios for Selected Sites

Site Code	Core Depth (cm)	SEM/AVS Component Ratios					Total SEM/AVS
		Cd	Cu	Ni	Pb	Zn	
ERP 1	0-8	0.0064	0.17	0.12	0.074	**1.1**	**1.5**
ERP 2	0-8	0.00014	0.0032	0.0035	0.0015	0.023	0.032
ERP 3	0-5	0.00052	0.013	0.021	0.0067	0.096	0.14
ERP 4	0-5	0.0011	0.016	0.033	0.0091	0.13	0.19
ERP 5	0-5	0.00040	0.011	0.0099	0.0092	0.087	0.12
DMIR 1	0-15	0.023	0.64	0.38	0.30	**3.1**	**4.4**
DMIR 2	0-15	0.0085	0.16	0.090	0.11	**1.3**	**1.6**
DMIR 3	0-15	0.0071	0.22	0.13	0.083	**1.1**	**1.5**
DMIR 4	0-15	0.053	**1.8**	0.82	0.51	**7.2**	**10**
MLH 1	0-12	0.0062	0.12	0.072	0.072	0.60	0.87
MLH 2	0-20	0.0023	0.049	0.026	0.012	0.16	0.25
MLH 3	0-15	0.0030	0.075	0.028	0.044	0.44	0.59
MLH 4	0-20	0.0034	0.085	0.040	0.064	0.70	0.90
MLH 5	0-17	0.0057	0.15	0.068	0.12	**1.2**	**1.6**
MLH 6	0-21	0.011	0.48	0.34	0.14	**1.7**	**2.7**
MLH 7	0-17	0.0038	0.094	0.051	0.075	0.78	**1.0**
MLH 8	0-15.5	0.0021	0.061	0.038	0.036	0.43	0.57
MLH 9	0-20	0.0035	0.076	0.036	0.063	0.72	0.90
MLH 10	0-20	0.0016	0.032	0.027	0.019	0.28	0.36
MLH 1	25-40	0.017	0.49	0.35	0.056	**1.3**	**2.2**
MLH 2	80-95	0.0026	0.085	0.032	0.026	0.29	0.43
MLH 3	37-52	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 4	30-50	0.027	**1.1**	**1.0**	0.11	**3.5**	**5.7**
MLH 5	32-47	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 6	25-40	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 7	72-87	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 8	60-76	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 9	52-79	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
MLH 10	75-95	0.043	**1.5**	0.74	**1.5**	**7.0**	**11**

Note: SEM/AVS ratios of >1.0 indicate that AVS binding potential will be exceeded, and metals will either be bioavailable in the interstitial water or will be available to bind with TOC.

Table 3-15. Continued

Site Code	Core Depth (cm)	SEM/AVS Component Ratios					Total SEM/AVS
		Cd	Cu	Ni	Pb	Zn	
HOB 1	0-5	0.0040	0.13	0.068	0.055	0.43	0.68
HOB 1	0-5 (VC)	0.022	**1.2**	0.27	0.14	**1.1**	**2.7**
HOB 2	0-15	0.0031	0.13	0.062	0.15	0.63	0.98
HOB 3	0-15	0.0033	0.13	0.058	0.12	0.58	0.90
HOB 4	0-15	0.0012	0.057	0.025	0.11	0.23	0.42
HOB 5	0-15	0.0019	0.088	0.033	0.11	0.39	0.62
HOB 6	0-15	0.0033	0.14	0.087	0.18	0.41	0.82
HOB 7	0-15	0.0043	0.25	0.092	0.28	0.89	**1.5**
HOB 8	0-5	0.029	**8.4**	0.67	**1.3**	**6.4**	**17**
HOB 9	0-5	0.073	**4.2**	**1.6**	0.99	**5.6**	**12**
HOB 10	0-10	0.0013	0.057	0.029	0.067	0.23	0.38
HOB 11	0-15	0.0031	0.20	0.067	0.43	0.74	**1.4**
HOB 12	0-10	0.0030	0.12	0.060	0.20	0.64	**1.0**
HOB 13	0-10	0.0035	0.27	0.074	0.32	0.70	**1.4**
HOB 14	0-15	0.0030	0.14	0.069	0.17	0.57	0.95
HOB 15	0-10	0.00055	0.021	0.0079	0.038	0.13	0.20
HOB 1	5-20	NA	NA	NA	NA	NA	NA
HOB 2	15-30	0.0026	0.11	0.057	0.097	0.49	0.76
HOB 3	15-30	0.037	**1.8**	0.65	**1.3**	**7.0**	**11**
HOB 4	15-30	0.11	**5.4**	**1.9**	**5.2**	**23**	**35**
HOB 5	15-30	0.071	**3.7**	**1.1**	**2.2**	**12**	**19**
HOB 6	15-30	NA	NA	NA	NA	NA	NA
HOB 7	15-30	0.023	**1.1**	0.26	**2.0**	**4.7**	**8.1**
HOB 10	15-30	0.029	**1.6**	0.66	**1.8**	**8.0**	**12**
HOB 11	10-25	NA	NA	NA	NA	NA	NA
HOB 14	15-30	NA	NA	NA	NA	NA	NA
HOB 15	15-30	0.00073	0.031	0.012	0.063	0.21	0.32

Note: SEM/AVS ratios of >1.0 indicate that AVS binding potential will be exceeded, and metals will either be bioavailable in the interstitial water or will be available to bind with TOC.

Table 3-15. Continued

Site Code	Core Depth (cm)	SEM/AVS Component Ratios					Total SEM/AVS
		Cd	Cu	Ni	Pb	Zn	
HOB 2	30-45	0.0044	0.22	0.08	0.20	0.97	1.5
HOB 3	30-45	NA	NA	NA	NA	NA	NA
HOB 4	30-45	0.084	**4.5**	**1.3**	**5.0**	**20**	**30**
HOB 5	30-45	0.089	**3.9**	**1.3**	**2.7**	**15**	**23**
HOB 6	30-45	NA	NA	NA	NA	NA	NA
HOB 7	30-45	0.11	**6.8**	**2.5**	**9.9**	**26**	**46**
HOB 10	30-45	NA	NA	NA	NA	NA	NA
HOB 11	25-40	NA	NA	NA	NA	NA	NA
HOB 14	30-45	NA	NA	NA	NA	NA	NA
HOB 15	30-45	0.00073	0.031	0.013	0.058	0.20	0.30
KMB 1	0-8	0.0084	0.25	0.26	0.060	**1.2**	**1.7**
KMB 2	0-12	0.0028	0.051	0.057	0.027	0.42	0.56
KMB 3	0-15	0.0020	0.050	0.033	0.034	0.40	0.52
KMB 4	0-15	0.00045	0.014	0.0093	0.0074	0.081	0.11
KMB 5	0-15	0.00053	0.018	0.013	0.0096	0.11	0.16

Note: SEM/AVS ratios of >1.0 indicate that AVS binding potential will be exceeded, and metals will either be bioavailable in the interstitial water or will be available to bind with TOC.

Table 3-16. Comparison of SEM Lead and Total Lead Concentrations in Howard's Bay

Site Code	Core Depth (cm)	SEM Pb Conc. (mg/kg) (dry wt.)	Total Pb Conc. (mg/kg) (dry wt.)
HOB 1	0-5	20.7	20.1
HOB 1	0-5 (Vibr)	8.2	9.1
HOB 2	0-15	111	111
HOB 3	0-15	83.2	92.5
HOB 4	0-15	177	78.5
HOB 5	0-15	139	89.3
HOB 6	0-15	47.5	28.1
HOB 7	0-15	142	163
HOB 8	0-5	97.9	113
HOB 9	0-5	21.0	34.1
HOB 10	0-10	50.7	94.5
HOB 11	0-15	277	215
HOB 12	0-10	161	132
HOB 13	0-10	253	269
HOB 14	0-15	108	104
HOB 15	0-10	172	194
	mean	117	109
standard	deviation	79.6	72.8
	median	108	94.5
range:	low	8.2	9.1
	high	277	269

Site Code	Core Depth (cm)	SEM Pb Conc. (mg/kg) (dry wt.)	Total Pb Conc. (mg/kg) (dry wt.)
HOB 1	5-20	<LOD	1500
HOB 2	15-30	105	99.5
HOB 3	15-30	100	73.1
HOB 4	15-30	139	125
HOB 5	15-30	84.3	67.3
HOB 6	15-30	0.75	8.17
HOB 7	15-30	111	123
HOB 10	15-30	69.4	76.2
HOB 11	10-25	14.3	37.0
HOB 14	15-30	92.4	67.7
HOB 15	15-30	154	132
	mean	79.1	210
standard	deviation	53.1	430
	median	84.3	73.1
range:	low	<LOD	8.17
	high	154	1500

Site Code	Core Depth (cm)	SEM Pb Conc. (mg/kg) (dry wt.)	Total Pb Conc. (mg/kg) (dry wt.)
HOB 2	30-45	116	182
HOB 3	30-45	19.1	42.0
HOB 4	30-45	129	1350
HOB 5	30-45	63.1	79.6
HOB 6	30-45	4.7	10.9
HOB 7	30-45	171	140
HOB 10	30-45	59.3	61.2
HOB 11	25-40	17.7	48.5
HOB 14	30-45	234	215
HOB 15	30-45	132	120
	mean	94.6	225
standard	deviation	74.7	400
	median	63.1	79.6
range:	low	4.7	10.9
	high	234	1350

* LOD = Limit of Detection

Table 3-17. Mercury Results for Selected Sites and Depth Profiles

Site Code	Replicate Type	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)	Mean Mercury (mg/kg) (dry wt.)
HOB 1		0-5	0.088	
HOB 1		0-5 (VC)	ND	
HOB 2		0-15	**0.490**	
HOB 3	ER	0-15	**0.486**	
HOB 3	ER	0-15	**0.382**	**0.434****
HOB 4		0-15	**0.320**	
HOB 5		0-15	**0.460**	
HOB 6	ER	0-15	0.052	
HOB 6	ER	0-15	**0.552**	**0.302****
HOB 7		0-15	**0.500**	
HOB 8		0-5(ponar)	**0.980**	
HOB 9		0-5	0.190	
HOB 10		0-10	**0.210**	
HOB 11		0-15	**0.540**	
HOB 12		0-10	**0.310**	
HOB 13	ER	0-10	**0.717**	
HOB 13	ER	0-10	**0.417**	**0.720****
HOB 14		0-15	**0.350**	
HOB 15	ER	0-10	**0.516**	
HOB 15	ER	0-10	**0.633**	
HOB 15	ER	0-10	**0.485**	
HOB 15	ER	0-10	**0.659**	**0.573****
HOB 1		5-20	ND	
HOB 2	ER	15-30	**0.506**	
HOB 2	ER	15-30	**0.440**	**0.473****
HOB 3	ER	15-30	**0.911**	
HOB 3	ER	15-30	**0.668**	**0.790****
HOB 4	ER	15-30	**0.603**	
HOB 4	ER	15-30	**0.600**	**0.602****
HOB 5		15-30	**0.760**	
HOB 6		15-30	ND	
HOB 7	ER	15-30	**0.242**	
HOB 7	ER	15-30	**0.207**	**0.224****
HOB 10		15-30	**0.350**	
HOB 11		10-25	0.030	
HOB 14		15-30	ND	
HOB 15		15-30	**2.600**	
HOB 2		30-45	**0.560**	
HOB 3		30-45	0.061	
HOB 4	ER	30-45	**0.678**	
HOB 4	ER	30-45	**0.666**	**0.672****
HOB 5		30-45	**0.550**	
HOB 6		30-45	ND	
HOB 7		30-45	**0.500**	
HOB 10		30-45	0.100	
HOB 11		25-40	0.160	
HOB 14		30-45	**0.230**	
HOB 15	ER	30-45	**0.640**	
HOB 15	ER	30-45	**0.654**	**0.647****

** = QC was exceeded
ER = Environmental replicate
Bold values exceed the OMOEE LEL value of 0.2 mg/kg mercury.
Bold and shaded values exceed the OMOEE SEL value of 2 mg/kg mercury.

Table 3-17. Continued

Site Code	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)
KMB 1	0-8	0.039
KMB 2	0-12	0.062
KMB 3	0-15	**0.280**
KMB 4	0-15	0.180
KMB 5	0-15	**0.220**
MLH 1	0-12	**0.240**
MLH 2	0-20	0.044
MLH 3	0-15	**0.710**
MLH 4	0-20	**0.500**
MLH 5	0-17	**0.460**
MLH 6	0-21	0.030
MLH 7	0-17	**0.320**
MLH 8	0-15.5	**0.230**
MLH 9	0-20	**0.450**
MLH 10	0-20	0.170
MLH 1	25-40	0.038
MLH 2	80-95	0.160
MLH 3	37-52	**0.360**
MLH 4	30-50	0.015
MLH 5	32-47	0.020
MLH 6	25-40	0.009
MLH 7	72-87	0.011
MLH 8	60-76	<LOD
MLH 9	52-79	0.035
MLH 10	75-95	**0.260**
MNS 1	0-10	**0.490**
MNS 2	0-12	**0.490**
MNS 3	0-15	**0.360**
MNS 4	0-15	**0.330**
MNS 4	0-15(VC)	**0.260**
MNS 5	0-10	**0.200**
MNS 5	5-20 (VC)	0.090
MNS 1	9-24	**0.300**
MNS 2	15-30	**0.340**
MNS 3	15-30	**0.380**
MNS 4	15-30	**0.270**
MNS 5	20-35	0.075

Site Code	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)
MNS 1	24-39	**0.300**
MNS 2	95-125	**1.500**
MNS 3	30-45	**0.580**
MNS 4	30-45	0.150
MNS 5	35-50	0.075
MNS 1	39-54	**0.380**
MNS 2	145-160	**1.200**
MNS 3	45-60	**0.680**
STP 1	0-15	**0.220**
STP 2	0-15	**0.890**
STP 3	0-10	**0.870**
STP 4	0-15	**0.230**
STP 5	0-15	**1.000**
STP 6	0-15	**0.320**
STP 7	0-15	**0.570**
STP 8	0-15	**1.300**
STP 10	0-10	**0.530**
STP 12	0-10	**0.310**
STP 1	15-30	**0.470**
STP 2	10-25	**1.700**
STP 3	15-30	**0.440**
STP 4	15-30	0.160
STP 6	7-23	**0.270**
STP 7	5-23	**0.680**
STP 8	15-30	**1.200**
STP 12	15-30	**0.990**
STP 1	30-45	**0.460**
STP 3	30-45	**0.220**
STP 4	30-45	**0.320**
STP 6	23-38	**0.410**
STP 12	30-46	**0.820**
STP 12	76-91	**1.800**
SUS 1	0-15	**0.280**
SUS 2	0-15	0.190
SUS 3	0-15	**0.240**
SUS 4	0-15	**0.320**
SUS 5	0-15	**0.220**

<LOD Mercury level below Limit of Detection
Bold values exceed the OMOEE LEL value of 0.2 mg/kg mercury.

Table 3-17. Continued

Site Code	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)	Site Code	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)
SUS 6	0-15	**0.260**	WLS 16	0-18	**0.920**
SUS 7	0-5	0.160	WLS 17	0-5	**0.230**
SUS 1	15-30	**0.370**	WLS 18	0-15	0.170
SUS 2	15-30	**0.470**	WLS 19	0-20	**0.810**
SUS 3	15-30	**0.600**	WLS 1	15-30	**0.320**
SUS 4	15-30	**0.270**	WLS 2	15-30	0.029
SUS 5	15-23	0.043	WLS 3	15-30	**0.290**
SUS 6	15-30	0.047	WLS 4	15-30	0.030
SUS 7	15-30	**0.270**	WLS 5	15-30	**1.700**
SUS 1	30-45	**0.490**	WLS 6	15-30	**0.480**
SUS 2	30-45	**0.970**	WLS 7	5-20	**0.900**
SUS 3	30-45	**0.490**	WLS 8	15-30	0.072
SUS 4	30-45	**0.240**	WLS 9	15-30	**0.400**
SUS 5	24-38	0.064	WLS 10	15-30	0.049
SUS 6	30-45	0.028	WLS 11	15-30	**1.300**
SUS 7	30-45	**0.240**	WLS 12	15-30	**0.260**
SUS 1	145-160	0.170	WLS 13	15-30	**2.900**
SUS 2	111-126	0.180	WLS 14	15-30	0.040
SUS 3	140-155	0.089	WLS 15	15-30	0.046
SUS 4	100-115	**0.590**	WLS 16	15-30	**0.980**
SUS 5	39-54	0.170	WLS 17	15-30	0.140
SUS 6	115-130	0.120	WLS 18	15-30	**0.280**
SUS 7	63-78	0.031	WLS 19	15-30	**0.400**
WLS 1	0-15	**0.260**	WLS 1	30-45	**0.410**
WLS 2	0-15	**0.260**	WLS 2	30-45	0.018
WLS 3	0-17	**0.360**	WLS 3	30-45	**1.000**
WLS 4	0-20	**0.540**	WLS 4	30-45	0.040
WLS 5	0-18	**0.760**	WLS 5	30-45	0.100
WLS 6	0-15	**0.520**	WLS 6	30-45	**0.520**
WLS 7	0-15	**0.600**	WLS 7	20-35	**0.310**
WLS 8	0-15	**1.500**	WLS 8	30-45	0.082
WLS 9	0-20	**0.720**	WLS 9	30-45	**0.660**
WLS 10	0-15	**0.260**	WLS 10	30-45	0.047
WLS 11	0-20	**0.550**	WLS 11	30-45	**0.760**
WLS 12	0-19	**0.750**	WLS 12	30-45	**3.900**
WLS 13	0-18	**0.790**	WLS 13	30-45	**0.760**
WLS 14	0-15	**0.720**	WLS 14	30-45	0.057
WLS 15	0-5	**0.470**	WLS 15	30-45	0.042

Bold values exceed the OMOEE LEL value of 0.2 mg/kg mercury.
Bold and shaded values exceed the OMOEE SEL value of 2 mg/kg mercury.

Table 3-17. Continued

Site Code	Core Depth (cm)	Mercury Conc. (mg/kg) (dry wt.)
WLS 16	30-45	**3.400**
WLS 17	30-45	0.140
WLS 18	30-45	0.037
WLS 19	30-45	0.056
WLS 1	189-204	**0.210**
WLS 2	167-182	0.140
WLS 3	173-188	0.038
WLS 4	105-120	0.047
WLS 5	135-150	0.088
WLS 6	235-250	0.160
WLS 7	35-50	**0.210**
WLS 8	90-105	0.042
WLS 9	145-160	**0.870**
WLS 10	135-150	0.029
WLS 11	145-160	0.190
WLS 12	153-168	0.046
WLS 13	155-170	0.030
WLS 14	140-155	0.035
WLS 15	165-180	**0.280**
WLS 16	160-175	0.050
WLS 17	50-65	0.088
WLS 18	156-171	0.024
WLS 19	181-196	0.027

Bold values exceed the OMOEE LEL value of 0.2 mg/kg mercury.
Bold and shaded values exceed the OMOEE SEL value of 2 mg/kg mercury.

Table 3-18. TCDD and TCDF Results for WLS and KMB Samples

Site Code	Core Depth (cm)	Replicate Type	TCDD (pg/g)	TCDD Detection Limit (pg/g)	TCDF (pg/g)	TCDF Detection Limit (pg/g)
WLS 1*	0-15		No Result	-	No Result	-
WLS 2*	0-15		No Result	-	No Result	-
WLS 3	0-17		7.1	-	NQ	20
WLS 4**	0-20		6.4	-	16	-
WLS 5	0-18		ND	14	22	-
WLS 6*	0-15		No Result	-	No Result	-
WLS 7**	0-15		4.4	-	28	-
WLS 8*	0-15		No Result	-	No Result	-
WLS 9**	0-20		ND	1.8	40	-
WLS 10	0-15		ND	4.1	NQ	13
WLS 11	0-20		7.7	-	8.4	-
WLS 12	0-19		3.4	-	6.4	-
WLS 13	0-18		ND	3.3	5.7	-
WLS 14	0-15		ND	6.8	NQ	7.0
WLS 15	0-5		ND	2.9	5.8	-
WLS 16	0-18		ND	6.5	9.5	-
WLS 17	0-5		ND	7.2	NQ	7.0
WLS 18	0-15		ND	2.9	7.5	-
WLS 18	0-15	AR	ND	4.0	5.5	-
WLS 19	0-20		ND	1.5	12	-
WLS 1	15-30		3.4	-	5.3	-
WLS 2	15-30		ND	1.5	ND	0.2
WLS 3	15-30		NQ	3.3	0.9	-
WLS 4	15-30		ND	3.7	ND	0.4
WLS 5	15-30		5.3	-	9.3	-
WLS 6	15-30		22	-	34	-
WLS 7	5-20		5.4	-	21	-
WLS 8	15-30		ND	2.4	ND	2.2
WLS 8	15-30	AR	ND	4.2	ND	0.3
WLS 10	15-30		ND	3.0	0.7	-
WLS 11	15-30		12	-	37	-

AR = Analytical Replicate; ND = Not Detected; NQ = Not Quantifiable
* No result due to 0% surrogate recovery
** Surrogate recoveries outside of acceptable QA limits

Table 3-18. Continued

Site Code	Core Depth (cm)	Replicate Type	TCDD (pg/g)	TCDD Detection Limit (pg/g)	TCDF (pg/g)	TCDF Detection Limit (pg/g)
WLS 12	15-30		ND	6.9	ND	1.1
WLS 13	15-30		6.8	-	12.3	-
WLS 14	15-30		ND	9.6	ND	0.5
WLS 15	15-30		ND	1.7	ND	0.2
WLS 16	15-30		3.7	-	NQ	8.1
WLS 17	15-30		ND	3.0	NQ	1.7
WLS 17	15-30	AR	ND	2.9	NQ	3.5
WLS 18	15-30		ND	4.7	ND	0.6
WLS 19	15-30		ND	3.0	ND	0.5
KMB 1	0-8		ND	5.3	NQ	1.6
KMB 2	0-12		ND	1.5	NQ	2.7
KMB 3	0-15		ND	4.6	NQ	13
KMB 4	0-15		ND	2.1	NQ	5.1
KMB 5	0-15		ND	1.6	NQ	9.1
KMB 5	0-15	AR	ND	2.8	NQ	8.8

AR = Analytical Replicate; ND = Not Detected; NQ = Not Quantifiable

Table 3-19. Screening PAH Results for Selected Sites

Site Code	Core Depth (cm)	Screening PAH Conc. (µg/kg) (dry wt.)
KMB 1	0-8	2,400
KMB 2	0-12	15,300
KMB 3	0-15	37,400
KMB 4	0-15	8,900
KMB 5	0-15	4,300
MLH 1	0-12	53,400
MLH 2	0-20	7,000
MLH 3	0-15	18,200
MLH 4	0-20	52,700
MLH 5	0-17	47,100
MLH 6	0-21	9,200
MLH 7	0-17	107,000
MLH 8	0-15.5	32,400
MLH 9	0-20	142,000
MLH 10	0-20	33,900
MLH 1	25-40	**900**
MLH 2	80-95	2,900
MLH 3	37-52	24,200
MLH 4	30-50	**1,800**
MLH 5	32-47	**1,200**
MLH 6	25-40	**1,600**
MLH 7	72-87	**1,100**
MLH 8	60-76	< 700
MLH 9	52-79	7,100
MLH 10	75-95	56,000
MNS 1	0-10	2,800
MNS 2	0-12	2,800
MNS 3	0-15	2,900
MNS 4	0-15	6,900
MNS 4	0-15(VC)	7,000
MNS 5	0-10	337,000
MNS 5	5-20 (VC)	3,800

Site Code	Core Depth (cm)	Screening PAH Conc. (µg/kg) (dry wt.)
MNS 1	9-24	**1,200**
MNS 2	15-30	4,700
MNS 3	15-30	**1,600**
MNS 4	15-30	223,000
MNS 5	20-35	41,000
MNS 1	24-39	**1,000**
MNS 2	95-125	3,700
MNS 3	30-45	**1,800**
MNS 4	30-45	404,000
MNS 5	35-50	6,000
MNS 1	39-54	2,400
MNS 2	145-160	2,300
MNS 3	45-60	6,600
SUS 1	0-15	5,800
SUS 2	0-15	317,000
SUS 3	0-15	7,100
SUS 4	0-15	228,000
SUS 5	0-15	135,000
SUS 6	0-15	223,000
SUS 7	0-5	140,000
SUS 1	15-30	**900**
SUS 2	15-30	**1,600**
SUS 3	15-30	2,900
SUS 4	15-30	216,000
SUS 5	15-23	240,900
SUS 6	15-30	39,500
SUS 7	15-30	84,500
SUS 1	30-45	**1,000**
SUS 2	30-45	**900**
SUS 3	30-45	375,000
SUS 4	30-45	6,200
SUS 5	24-38	83,600

Limit of Quantitation (LOQ) = 2,000 µg/Kg.
Values entered in bold are greater than the limit of detection (LOD), but less than the LOQ.

Table 3-19. Continued

Site Code	Core Depth (cm)	Screening PAH Conc. (µg/kg) (dry wt.)
SUS 6	30-45	34,900
SUS 7	30-45	88,200
SUS 1	145-160	78,000
SUS 2	111-126	5,800
SUS 3	140-155	37,100
SUS 4	100-115	457,000
SUS 5	39-54	155,000
SUS 6	115-130	93,900
SUS 7	63-78	14,800
WLS 1	0-15	48,600
WLS 2	0-15	16,900
WLS 3	0-17	222,000
WLS 4	0-20	3,500
WLS 5	0-18	83,000
WLS 6	0-15	23,400
WLS 7	0-15	74,300
WLS 8	0-15	411,000
WLS 9	0-20	37,200
WLS 10	0-15	18,200
WLS 11	0-20	40,000
WLS 12	0-19	23,100
WLS 13	0-18	52,400
WLS 14	0-15	34,700
WLS 15	0-5	32,400
WLS 16	0-18	133,000
WLS 17	0-5	44,200
WLS 18	0-15	224,000
WLS 19	0-20	48,100
WLS 1	15-30	14,600
WLS 2	15-30	4,200
WLS 3	15-30	55,900
WLS 4	15-30	17,500
WLS 5	15-30	65,300
WLS 6	15-30	87,100
WLS 7	5-20	188,000
WLS 8	15-30	**800**

Site Code	Core Depth (cm)	Screening PAH Conc. (µg/kg) (dry wt.)
WLS 9	15-30	49,500
WLS 10	15-30	**1,400**
WLS 11	15-30	145,000
WLS 12	15-30	30,600
WLS 13	15-30	191,000
WLS 14	15-30	**900**
WLS 15	15-30	4,100
WLS 16	15-30	96,600
WLS 17	15-30	21,400
WLS 18	15-30	**900**
WLS 19	15-30	10,700
WLS 1	30-45	574,000
WLS 2	30-45	**900**
WLS 3	30-45	134,000
WLS 4	30-45	8,300
WLS 5	30-45	9,000
WLS 6	30-45	150,000
WLS 7	20-35	122,000
WLS 8	30-45	**1,200**
WLS 9	30-45	146,000
WLS 10	30-45	3,300
WLS 11	30-45	141,000
WLS 12	30-45	172,000
WLS 13	30-45	135,000
WLS 14	30-45	**900**
WLS 15	30-45	4,800
WLS 16	30-45	370,000
WLS 17	30-45	146,000
WLS 18	30-45	**700**
WLS 19	30-45	28,900
WLS 1	189-204	19,000
WLS 2	167-182	15,600
WLS 3	173-188	**1,300**
WLS 4	105-120	**1,900**
WLS 5	135-150	27,900
WLS 6	235-250	21,000

Limit of Quantitation (LOQ) = 2,000 µg/Kg.
Values entered in bold are greater than the limit of detection (LOD), but less than the LOQ.

Table 3-19. Continued

Site Code	Core Depth (cm)	Screening PAH Conc. (µg/kg) (dry wt.)
WLS 7	35-50	34,600
WLS 8	90-105	2,100
WLS 9	145-160	110,000
WLS 10	135-150	**1,000**
WLS 11	145-160	21,300
WLS 12	153-168	**1,000**
WLS 13	155-170	**800**
WLS 14	140-155	**800**
WLS 15	165-180	62,700
WLS 16	160-175	**1,300**
WLS 17	50-65	24,800
WLS 18	156-171	< 700
WLS 19	181-196	< 700

Limit of Quantitation (LOQ) = 2,000 µg/Kg.
Values entered in bold are greater than the limit of detection (LOD), but less than the LOQ.

Table 3-20. PAH Results (by GC/MS) for Selected Sites

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
KMB																		
1-C	0-8	1	3	9	41	46	75	27	21	40	8	4	52	27	12	17	46	430
2-C	0-12	3	8	16	98	100	160	19	33	97	13	7	130	42	28	32	120	900
3-D	0-15	< 31	< 31	60	**320**	290	360	85	140	320	54	41	440	160	150	130	370	3,000
4-D	0-15	< 30	< 30	31	200	210	240	160	110	210	37	< 30	280	120	80	90	230	2,000
5-D	0-15	< 39	< 39	57	**360**	**390**	420	**480**	180	**380**	**66**	41	480	**210**	91	150	380	3,700
MLH																		
1-D	0-12	<26	38	100	260	210	350	120	110	**340**	28	43	670	94	130	330	**580**	3,400
2-C	0-20	10	26	14	28	20	35	11	12	33	<11	22	98	<11	130	70	71	590
3-D	0-15	25	70	100	270	230	330	100	98	330	33	59	640	110	430	300	480	3,600
4-D	0-20	<67	220	**310**	**1,000**	**940**	1,300	**420**	**420**	**1,100**	**130**	160	**1,900**	**400**	1,300	**650**	**1,500**	**12,000**
5-D	0-17	<69	170	**220**	**780**	**750**	1,000	**430**	**400**	**830**	**110**	130	**1,400**	**330**	850	550	**1,200**	**9,200**
6-C	0-21	3	17	26	84	71	110	41	28	93	12	11	160	31	63	55	130	940
7-C	0-17	26	160	**290**	**1,100**	**1,300**	1,600	**710**	**600**	**1,100**	**170**	100	**1,800**	**680**	660	460	**1,500**	**12,000**
8-D	0-15.5	27	80	140	**450**	**440**	610	**280**	230	**570**	**61**	59	**1,100**	**220**	240	420	**870**	**5,800**
9-D	0-20	<68	200	**350**	**1,200**	**1,100**	1,400	**510**	**480**	**1,300**	**150**	150	**2,200**	**400**	900	**690**	**1,700**	**13,000**
10-D	0-20	63	49	170	**420**	**460**	600	**310**	**250**	**520**	**69**	91	**860**	**260**	350	390	**690**	**5,600**
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-20. Continued

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
MLH																		
1-C	25-40	5	12	17	64	57	80	32	26	62	8	7	120	33	23	47	100	690
2-C	80-95	12	67	54	110	63	120	23	32	130	10	45	340	21	1,000	110	260	2,400
3-D	37-52	<26	54	68	250	220	330	120	120	330	33	44	610	110	260	270	**520**	3,400
4	30-50	2	6	4	13	11	14	32	5	13	2	3	31	8	15	16	29	200
5	32-47	<0.96	<0.96	<0.96	1	2	3	2	<0.96	2	<0.96	<0.96	4	2	1	3	4	27
6	25-40	1	3	2	5	4	6	20	2	5	<0.89	1	14	3	10	8	12	96
7	72-87	<0.9	<0.9	<0.9	4	3	5	2	1	4	<0.9	<0.9	8	2	7	3	8	50
8	60-76	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	2	<0.8	<0.8	8
9	52-79	<2.3	<2.3	<2.3	3	3	7	7	2	5	<2.3	<2.3	8	3	6	6	7	62
10-C	75-95	99	200	**370**	**1,400**	**1,400**	2,000	**840**	**720**	**1,300**	**190**	**240**	**2,200**	**870**	950	**1,100**	**2,100**	**16,000**
MNS																		
1-C	0-10	260	53	**850**	**4,100**	**3,900**	6,700	**920**	**1,500**	**9,800**	**620**	**380**	**9,500**	**1,700**	140	**4,500**	**7,700**	**53,000**
2-C	0-12	310	140	**780**	**4,600**	**3,600**	6,600	**630**	**2,200**	**5,700**	**430**	**440**	**14,000**	**2,200**	160	**5,700**	**9,800**	**57,000**
3-C	0-15	650	130	**1,400**	**5,300**	**3,900**	7,100	**890**	**1,900**	**6,500**	**440**	**780**	**13,000**	**2,100**	390	**8,400**	**9,800**	**63,000**
4-C	0-15	810	190	**1,800**	**8,000**	**5,000**	9,300	**850**	**3,100**	**8,600**	**580**	**1,100**	**20,000**	**2,800**	330	**12,000**	**15,000**	**89,000**
5-C	0-10	230	130	**700**	**2,500**	**1,900**	3,100	**470**	**830**	**2,700**	**200**	**290**	**5,500**	**950**	110	**3,300**	**4,500**	**27,000**
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-20. Continued

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.) Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
MNS																		
1-C	24-39	790	190	**2,000**	**6,800**	**4,600**	8,100	**790**	**2,100**	**7,900**	**530**	**960**	**17,000**	**2,400**	420	**10,000**	**13,000**	**78,000**
2-C	95-125	1,300	350	**2,600**	**10,000**	**7,200**	11,000	**1,800**	**2,300**	**10,000**	**740**	**1,800**	**23,000**	**3,500**	690	**16,000**	**20,000**	**110,000**
3-C	30-45	980	240	**2,000**	**8,300**	**5,400**	9,500	**780**	**2,800**	**8,500**	**640**	**1,400**	**20,000**	**3,100**	520	**13,000**	**14,000**	**91,000**
4-C	15-30	7,600	570	**13,000**	**22,000**	**17,000**	21,000	**4,700**	**8,800**	**22,000**	**1,600**	**9,300**	**65,000**	**7,700**	5,400	**75,000**	**44,000**	**320,000**
5-C	20-35	55	49	120	**450**	**380**	520	96	190	**490**	46	54	**1,200**	**210**	23	**640**	**1,200**	**5,700**
STP																		
12-D	0-10	74	<26	110	**460**	**430**	540	**170**	230	**530**	**80**	110	**860**	**250**	90	**650**	**700**	**5,300**
12-C	15-30	220	120	**220**	**650**	**480**	710	94	**280**	**700**	**99**	**410**	**1,200**	**260**	110	**2,600**	**1,100**	**9,200**
12-D	30-46	59	39	140	**510**	**530**	670	**210**	210	**630**	**96**	120	880	**270**	150	500	**800**	**5,800**
12-D	76-91	83	82	**360**	**1,300**	**1,300**	1,900	**360**	**450**	**1,300**	**220**	**230**	**2,600**	**670**	240	**1,200**	**2,200**	**14,000**
SUS																		
1-D	0-15	82	40	170	**610**	**610**	890	**410**	**300**	**740**	**120**	110	**1,300**	**370**	120	**780**	**1,100**	**7,800**
2-C	0-15	110	45	**240**	**830**	**870**	1,200	**540**	**390**	**950**	**160**	160	**2,100**	**480**	170	**1,000**	**1,700**	**11,000**
3-C	0-15	1,700	87	**2,800**	**3,600**	**3,300**	4,100	**1,200**	**1,600**	**3,400**	**540**	**2,600**	**9,100**	**1,500**	530	**10,000**	**7,200**	**53,000**
4-C	0-15	230	100	**430**	**1,400**	**1,600**	2,100	**1,000**	**800**	**1,700**	**270**	**320**	**3,500**	**850**	240	**2,200**	**3,000**	**20,000**
5-C	0-15	110	31	**260**	**740**	**780**	980	**460**	**310**	**790**	**140**	140	**1,700**	**420**	110	**1,000**	**1,400**	**9,400**
6-C	0-15	190	<53	**720**	**1,800**	**2,100**	2,200	**960**	**750**	**1,900**	**290**	**190**	**4,500**	**860**	63	**2,500**	**4,900**	**24,000**
7-D	0-5	56	21	150	**440**	**430**	560	**260**	190	**480**	**79**	91	**870**	**220**	89	**620**	**750**	**5,300**
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-20. Continued

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
SUS																		
1-C	30-45	360	130	**500**	**1,000**	**960**	1,400	**480**	**400**	**1,400**	**130**	**530**	**2,500**	**430**	280	**2,600**	**2,100**	**15,000**
2-C	30-45	220	<71	**310**	**980**	**1,100**	1,400	**410**	**480**	**1,300**	**130**	**260**	**2,200**	**420**	250	**1,700**	**2,200**	**13,000**
3-C	30-45	78	64	200	**520**	**550**	760	**240**	**250**	**600**	**72**	130	**1,200**	**240**	100	**910**	**980**	**6,900**
4-C	30-45	200	210	**440**	**1,400**	**1,500**	1,800	**680**	**610**	**1,400**	**180**	**250**	**3,000**	**650**	190	**1,600**	**2,700**	**17,000**
5-D	24-38	28	<17	62	180	190	280	100	100	210	25	49	430	93	46	350	370	2,500
6-D	30-45	33	<17	58	140	120	180	75	75	150	<17	50	360	63	81	380	300	2,100
7-D	30-45	61	30	100	240	250	320	120	120	240	31	68	570	110	60	440	520	3,300
WLS																		
1-C	0-15	88	88	**260**	**1,400**	**1,300**	2,200	**850**	**720**	**1,700**	**260**	110	**2,900**	**870**	63	**930**	**2,400**	**16,000**
2-C	0-15	53	540	160	**860**	**790**	1,200	**510**	**370**	**920**	**150**	71	**1,600**	**510**	58	**590**	**1,300**	**9,700**
3-C	0-17	70	78	**220**	**920**	**830**	1,400	**550**	**400**	**960**	**170**	100	**1,700**	**560**	99	**700**	**1,400**	**10,000**
4-C	0-20	58	87	190	**1,000**	**920**	1,500	**600**	**490**	**1,100**	**190**	83	**1,900**	**630**	74	**600**	**1,600**	**11,000**
5-D	0-18	47	86	170	**860**	**780**	1,300	**510**	**400**	**890**	**160**	80	**1,500**	**530**	170	420	**1,300**	**9,200**
6-D	0-15	45	77	170	**880**	**860**	1,400	**560**	**380**	**940**	**170**	74	**1,600**	**580**	140	470	**1,400**	**9,700**
7-C	0-15	30	52	100	**410**	**500**	660	**350**	**270**	**530**	**69**	50	**880**	**280**	95	320	**820**	**5,400**
8-C	0-15	72	140	**260**	**1,100**	**1,000**	1,600	**600**	**480**	**1,200**	**200**	140	**1,900**	**640**	310	**670**	**1,700**	**12,000**
9-C	0-20	42	76	150	**720**	**710**	1,100	**440**	**350**	**780**	**140**	73	**1,300**	**470**	150	400	**1,100**	**8,000**
10-C	0-15	17	35	56	**230**	270	380	**180**	150	290	42	31	**460**	**140**	74	150	440	2,900
11-C	0-20	36	80	130	**520**	**620**	900	**410**	**300**	**690**	**74**	70	**1,000**	**330**	220	370	**930**	**6,700**
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-20. Continued

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
WLS 12-D	0-19	42	74	170	**580**	**590**	810	**330**	**270**	**690**	**85**	110	**1,200**	**290**	370	540	**1,000**	**7,200**
13-D	0-18	30	65	140	**470**	**470**	650	**260**	230	**570**	**71**	86	**970**	**240**	290	420	**840**	**5,800**
14-D	0-15	43	91	180	**730**	**750**	1,000	**460**	**300**	**790**	**110**	97	**1,400**	**420**	230	520	**1,200**	**8,300**
15-D	0-5	<22	29	64	250	250	350	150	120	280	35	36	570	130	83	190	**490**	3,000
16-D	0-18	46	83	190	**600**	**590**	820	**350**	**280**	**740**	**86**	110	**1,200**	**290**	400	550	**1,100**	**7,400**
17-D	0-5	<21	28	65	220	220	320	120	100	270	28	39	500	100	170	200	470	2,900
18-D	0-15	<12	21	37	120	140	200	83	74	150	21	22	280	76	71	100	250	1,600
19-D	0-20	36	83	160	**540**	**600**	780	**300**	**280**	**640**	**88**	97	**990**	**320**	400	380	**900**	**6,600**
1-D	189-204	<25	<25	46	220	200	280	130	100	250	33	33	440	110	67	160	370	2,500
2-D	167-182	<29	<29	50	270	220	350	150	110	290	45	<29	510	140	46	150	460	2,800
3	173-188	<1.5	<1.5	<1.5	2	3	5	3	<1.5	2	<1.5	<1.5	7	2	2	3	5	38
4	105-120	2	2	5	16	13	21	13	7	21	3	4	39	8	10	22	32	220
5	135-150	3	4	5	21	14	27	15	7	19	3	6	37	12	11	18	31	230
6-D	235-250	<20	<20	31	110	90	130	52	50	130	<20	24	250	50	80	100	210	1,300
7-D	35-50	36	<17	64	190	160	230	110	77	210	25	43	440	90	56	250	370	2,400
8	90-105	<4	<4	<4	<4	<4	<4	25	<4	<4	<4	<4	9	6	5	5	8	79
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-20. Continued

Site Code	Core Depth (cm)	PAHs (µg/kg dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
WLS 9-C	145-160	48	84	180	**710**	**600**	830	**350**	**310**	**780**	**94**	110	**1,500**	**330**	180	**570**	**1,200**	**7,900**
10-C	135-150	3	3	8	22	20	24	13	10	24	3	5	47	10	17	20	39	270
11-D	145-160	<20	23	47	150	130	180	81	69	160	<20	33	320	68	96	140	270	1,800
12	153-168	<1.4	<1.4	<1.4	2	2	4	6	2	2	<1.4	<1.4	5	2	4	3	5	40
13	155-170	<1.2	<1.2	<1.2	<1.2	<1.2	2	<1.2	2	<1.2	<1.2	<1.2	2	<1.2	3	2	3	19
14	140-155	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	2	<1.2	<1.2	1	1	12
15-D	165-180	28	32	85	310	270	360	150	150	**360**	42	61	610	150	100	290	**510**	3,500
16	160-175	<1.3	<1.3	<1.3	2	2	5	5	<1.3	2	<1.3	<1.3	5	2	2	3	4	35
17-D	50-65	15	23	57	160	140	190	77	65	170	19	41	320	65	170	160	290	2,000
18	156-171	<1	<1	<1	<1	<1	1	7	<1	<1	<1	<1	<1	<1	2	<1	<1	17
19	181-196	<1.1	<1.1	<1.1	<1.1	<1.1	2	<1.1	<1.1	<1.1	<1.1	<1.1	1	<1.1	<1.1	<1.1	1	12
Lowest Effect Level		NA	NA	220	320	370	NA	170	240	340	60	190	750	200	NA	560	490	4,000

Bold values exceed OMOEE LEL values.
NA = Not applicable.
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.

PAH Codes:
Acene = Acenaphthene
Aceny = Acenaphthylene
Anth = Anthracene
Bena = Benz(a)anthracene
Benap = Benzo(a)pyrene
Benb = Benzo(b)fluoroanthene
Beng = Benzo(g,h,i)perylene
Benk = Benzo(k)fluoroanthene
Chry = Chrysene
Diben = Dibenz(a,h)anthracene
Fluo = Fluorene
Flut = Fluoranthene
Indp = Indeno(1,2,3 - cd)pyrene
Naph = Naphthalene
Phen = Phenanthrene
Pyrn = Pyrene

Table 3-21. TOC-normalized PAH Results for Selected Sites

Site Code	Core Depth (cm)	Normalized PAHs (µg/kg oc dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
KMB																		
1-C	0-8	59	160	400	1,900	2,100	3,400	1,200	960	1,800	370	170	2,400	1,200	540	770	2,100	20,000
2-C	0-12	160	440	940	5,800	5,900	9,400	1,100	1,900	5,700	760	400	7,600	2,500	1,600	1,900	7,000	53,000
3-D	0-15	500	500	1,900	10,000	9,400	12,000	2,700	4,500	10,000	1,700	1,300	14,000	5,200	4,800	4,200	12,000	97,000
4-D	0-15	680	680	1,400	9,100	9,500	11,000	7,300	5,000	9,500	1,700	680	13,000	5,400	3,600	4,100	10,000	91,000
5-D	0-15	700	700	2,000	13,000	14,000	15,000	17,000	6400	14,000	2,400	1,500	17,000	7,500	3,200	5,400	14,000	130,000
MLH																		
1-D	0-12	260	760	2,000	5,200	4,200	7,000	2,400	2,200	6,800	560	860	13,000	1,900	2,600	6,600	12,000	68,000
2-C	0-20	140	370	200	390	280	490	160	170	460	77	310	1,400	77	1,800	990	1,000	8,300
3-D	0-15	210	580	830	2,200	1,900	2,800	830	820	2,800	280	490	5,300	920	3,600	2,500	4,000	30,000
4-D	0-20	510	3,300	4,700	15,000	14,000	20,000	6,400	6,400	17,000	2,000	2,400	29,000	6,000	20,000	9,800	23,000	180,000
5-D	0-17	530	2,600	3,400	12,000	12,000	15,000	6,600	6,200	13,000	1,700	2,000	22,000	5,100	13,000	8,500	18,000	140,000
6-C	0-21	380	1,900	2,900	9,400	8,000	12,000	4,600	3,100	10,000	1,300	1,200	18,000	3,500	7,100	6,200	15,000	100,000
7-C	0-17	680	4,200	7,600	29,000	34,000	42,000	19,000	16,000	29,000	4,500	2,600	47,000	18,000	17,000	12,000	39,000	320,000
8-D	0-15.5	560	1,700	2,900	9,400	9,200	13,000	5,800	4,800	12,000	1,300	1,200	23,000	4,600	5,000	8,800	18,000	120,000
9-D	0-20	540	3,200	5,600	19,000	17,000	22,000	8,100	7,600	21,000	2,400	2,400	35,000	6,300	14,000	11,000	27,000	210,000
10-D	0-20	1,800	1,400	5,000	12,000	14,000	18,000	9,100	7,400	15,000	2,000	2,700	25,000	7,600	10,000	11,000	20,000	160,000
1-C	25-40	230	600	850	3,200	2,800	4,000	1,600	1,300	3,100	420	340	6,000	1,600	1,200	2,400	5,000	34,000
2-C	80-95	63	350	280	580	330	630	120	170	680	53	240	1,800	110	5,300	580	1,400	13,000
3-D	37-52	87	360	450	1,700	1,500	2,200	800	800	2,200	220	290	4,100	730	1,700	1,800	3,500	23,000
4	30-50	88	250	160	540	460	580	1,300	210	540	100	130	1,300	320	620	670	1,200	8,300
5	32-47	23	23	23	67	76	130	100	23	81	23	23	200	76	67	130	210	1,300
OMOEE SEL		NA	NA	370,000	1,480,000	1,440,000	NA	320,000	1,340,000	460,000	130,000	160,000	1,020,000	320,000	NA	950,000	850,000	10,000,000

NA = Not applicable
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-21. Continued

Site Code	Core Depth (cm)	Normalized PAHs (µg/kg oc dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
MLH																		
6	25-40	41	130	79	200	170	240	830	79	210	19	58	580	120	420	340	500	4,000
7	72-87	35	35	35	310	230	350	170	100	320	35	35	630	160	500	240	630	3,800
8	60-76	220	220	220	220	220	220	220	220	220	220	220	220	220	1,200	220	220	4,500
9	52-79	8	8	8	20	21	43	45	15	31	8	8	55	19	42	37	47	410
10-C	75-95	2,400	4,900	9,000	34,000	34,000	49,000	20,000	18,000	32,000	4,600	5,800	54,000	21,000	23,000	27,000	51,000	390,000
MNS																		
1-C	0-10	6,500	1,300	21,000	100,000	98,000	170,000	23,000	38,000	240,000	16,000	9,500	240,000	42,000	3,500	110,000	190,000	1,300,000
2-C	0-12	6,500	2,900	16,000	96,000	75,000	140,000	13,000	46,000	120,000	9,000	9,200	290,000	46,000	3,300	120,000	200,000	1,200,000
3-C	0-15	20,000	4,100	44,000	160,000	120,000	220,000	28,000	59,000	200,000	14,000	24,000	410,000	66,000	12,000	260,000	310,000	2,000,000
4-C	0-15	23,000	5,400	51,000	230,000	140,000	260,000	24,000	88,000	240,000	16,000	31,000	570,000	80,000	9,400	340,000	430,000	2,500,000
5-C	0-10	9,600	5,400	29,000	100,000	79,000	130,000	20,000	34,000	110,000	8,300	12,000	230,000	40,000	4,600	140,000	190,000	1,100,000
1-C	24-39	19,000	4,500	48,000	160,000	110,000	190,000	19,000	50,000	190,000	13,000	23,000	400,000	57,000	10,000	240,000	310,000	1,800,000
2-C	95-125	19,000	5,200	39,000	150,000	110,000	160,000	27,000	34,000	150,000	11,000	27,000	340,000	52,000	10,000	240,000	300,000	1,600,000
3-C	30-45	24,000	6,000	50,000	210,000	140,000	240,000	20,000	70,000	210,000	16,000	35,000	500,000	78,000	13,000	320,000	350,000	2,300,000
4-C	15-30	400,000	30,000	**680,000**	1,200,000	890,000	1,100,000	250,000	460,000	**1,200,000**	84,000	**490,000**	**3,400,000**	**400,000**	280,000	**3,900,000**	**2,300,000**	**17,000,000**
5-C	20-35	8,200	7,300	18,000	67,000	57,000	78,000	14,000	28,000	73,000	6,900	8,100	180,000	31,000	3,400	96,000	180,000	850,000
OMOEE SEL		NA	NA	370,000	1,480,000	1,440,000	NA	320,000	1,340,000	460,000	130,000	160,000	1,020,000	320,000	NA	950,000	850,000	10,000,000

NA = Not applicable
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-21. Continued

Site Code	Core Depth (cm)	Normalized PAHs (µg/kg oc dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
STP																		
12-D	0-15	1,800	320	2,700	11,000	10,000	13,000	4,100	5,600	13,000	2,000	2,700	21,000	6,100	2,200	16,000	17,000	130,000
12-C	15-30	4,700	2,600	4,700	14,000	10,000	15,000	2,000	6,000	15,000	2,100	8,700	26,000	5,500	2,300	55,000	23,000	200,000
12-D	30-46	1,600	1,000	3,800	14,000	14,000	18,000	5,700	5,700	17,000	2,600	3,200	24,000	7,300	4,000	14,000	22,000	160,000
12-D	76-91	1,300	1,300	5,600	20,000	20,000	30,000	5,600	7,000	20,000	3,400	3,600	41,000	10,000	3,800	19,000	34,000	220,000
SUS																		
1-D	0-15	1,700	850	3,600	13,000	13,000	19,000	8,700	6,400	16,000	2,600	2,300	28,000	7,900	2,600	16,000	23,000	160,000
2-C	0-15	3,100	1,300	6,800	24,000	25,000	34,000	15,000	11,000	27,000	4,600	4,600	60,000	14,000	4,800	28,000	48,000	310,000
3-C	0-15	35,000	1,800	57,000	73,000	67,000	84,000	24,000	33,000	69,000	11,000	53,000	180,000	31,000	11,000	200,000	150,000	1,100,000
4-C	0-15	5,300	2,300	10,000	32,000	37,000	49,000	23,000	19,000	40,000	6,300	7,400	81,000	20,000	5,600	51,000	70,000	460,000
5-C	0-15	4,800	1,300	11,000	32,000	34,000	43,000	20,000	13,000	34,000	6,100	6,100	74,000	18,000	4,800	43,000	61,000	410,000
6-C	0-15	10,000	1,400	38,000	95,000	110,000	120,000	50,000	39,000	100,000	15,000	10,000	240,000	45,000	3,300	130,000	260,000	1,300,000
7-D	0-5	2,100	780	5,600	16,000	16,000	21,000	9,600	7,000	18,000	2,900	3,400	32,000	8,100	3,300	23,000	28,000	200,000
1-C	30-45	2,400	870	3,300	6,700	6,400	9,300	3,200	2,700	9,300	870	3,500	17,000	2,900	1,900	17,000	14,000	100,000
2-C	30-45	2,000	320	2,800	8,900	10,000	13,000	3,700	4,400	12,000	1,200	2,400	20,000	3,800	2,300	15,000	20,000	120,000
3-C	30-45	2,200	1,800	5,600	14,000	15,000	21,000	6,700	6,900	17,000	2,000	3,600	33,000	6,700	2,800	25,000	27,000	190,000
4-C	30-45	4,600	4,900	10,000	32,000	35,000	42,000	16,000	14,000	32,000	4,200	5,800	70,000	15,000	4,400	37,000	63,000	400,000
5-D	24-38	3,500	1,100	7,800	22,000	24,000	35,000	12,000	12,000	26,000	3,100	6,100	54,000	12,000	5,800	44,000	46,000	310,000
6-D	30-45	12,000	3,000	21,000	50,000	43,000	64,000	27,000	27,000	54,000	3,000	18,000	130,000	22,000	29,000	140,000	110,000	750,000
7-D	30-45	4,400	2,100	7,100	17,000	18,000	23,000	8,600	8,600	17,000	2,200	4,900	41,000	7,900	4,300	31,000	37,000	240,000
OMOEE SEL		NA	NA	370,000	1,480,000	1,440,000	NA	320,000	1,340,000	460,000	130,000	160,000	1,020,000	320,000	NA	950,000	850,000	10,000,000

NA = Not applicable
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-21. Continued

Site Code	Core Depth (cm)	Normalized PAHs (µg/kg oc dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
WLS																		
1-C	0-15	3,000	3,000	9,000	48,000	45,000	76,000	29,000	25,000	59,000	9,000	3,800	100,000	30,000	2,200	32,000	83,000	550,000
2-C	0-15	2,300	23,000	7,000	37,000	34,000	52,000	22,000	16,000	40,000	6,500	3,100	70,000	22,000	2,500	26,000	56,000	420,000
3-C	0-17	2,200	2,500	7,100	30,000	27,000	45,000	18,000	13,000	31,000	5,500	3,200	55,000	18,000	3,200	22,000	45,000	320,000
4-C	0-20	1,900	2,900	6,300	33,000	31,000	50,000	20,000	16,000	37,000	6,300	2,800	63,000	21,000	2,500	20,000	53,000	370,000
5-D	0-18	960	1,800	3,500	18,000	16,000	26,000	10,000	8,200	18,000	3,300	1,600	31,000	11,000	3,500	8,600	26,000	190,000
6-D	0-15	1,200	2,100	4,600	24,000	23,000	38,000	15,000	10,000	25,000	4,600	2,000	43,000	16,000	3,800	13,000	38,000	260,000
7-C	0-15	860	1,500	2,800	12,000	14,000	19,000	10,000	7,700	15,000	2,000	1,400	25,000	8,000	2,700	9,100	23,000	150,000
8-C	0-15	1,600	3,100	5,800	24,000	22,000	36,000	13,000	11,000	27,000	4,400	3,100	42,000	14,000	6,900	15,000	38,000	270,000
9-C	0-20	1,100	2,000	3,900	19,000	19,000	29,000	12,000	9,200	20,000	3,700	1,900	34,000	12,000	3,900	10,000	29,000	210,000
10-C	0-15	1,000	2,000	3,300	14,000	16,000	22,000	10,000	8,800	17,000	2,500	1,800	27,000	8,200	4,400	8,800	26,000	170,000
11-C	0-20	1,000	2,200	3,600	14,000	17,000	25,000	11,000	8,300	19,000	2,000	1,900	28,000	9,200	6,100	10,000	26,000	190,000
12-D	0-19	860	1,500	3,500	12,000	12,000	16,000	6,700	5,500	14,000	1,700	2,200	24,000	5,900	7,600	11,000	20,000	150,000
13-D	0-18	640	1,400	3,000	10,000	10,000	14,000	5,500	4,900	12,000	1,500	1,800	21,000	5,100	6,200	8,900	18,000	120,000
14-D	0-15	770	1,600	3,200	13,000	13,000	18,000	8,200	5,400	14,000	2,000	1,700	25,000	7,500	4,100	9,300	21,000	150,000
15-D	0-5	420	1,100	2,500	9,600	9,600	13,000	5,800	4,600	11,000	1,300	1,400	22,000	5,000	3,200	7,300	19,000	120,000
16-D	0-18	980	1,800	4,000	13,000	12,000	17,000	7,400	6,000	16,000	1,800	2,300	26,000	6,200	8,500	12,000	23,000	160,000
17-D	0-5	380	1,000	2,300	7,800	7,800	11,000	4,300	3,600	9,600	1,000	1,400	18,000	3,600	6,100	7,100	17,000	100,000
18-D	0-15	220	780	1,400	4,400	5,200	7,400	3,100	2,700	5,600	780	820	10,000	2,800	2,600	3,700	9,200	59,000
19-D	0-20	820	1,900	3,600	12,000	14,000	18,000	6,800	6,400	14,000	2,000	2,200	22,000	7,300	9,100	8,600	20,000	150,000
OMOEE SEL		NA	NA	370,000	1,480,000	1,440,000	NA	320,000	1,340,000	460,000	130,000	160,000	1,020,000	320,000	NA	950,000	850,000	10,000,000

NA = Not applicable
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.
Full name of PAH codes at end of Table.

Table 3-21. Continued

Site Code	Core Depth (cm)	Normalized PAHs (µg/kg oc dry wt.)																
		Acene	Aceny	Anth	Bena	Benap	Benb	Beng	Benk	Chry	Diben	Fluo	Flut	Indp	Naph	Phen	Pyrn	Total
WLS																		
1-D	189-204	340	340	1,200	5,900	5,400	7,600	3,500	2,700	6,800	890	890	12,000	3,000	1,800	4,300	10,000	68,000
2-D	167-182	280	280	960	5,200	4,200	6,700	2,900	2,100	5,600	860	280	9,800	2,700	880	2,900	8,800	54,000
3	173-188	12	12	12	36	48	77	52	12	38	12	12	110	28	26	51	82	620
4	105-120	51	44	130	370	300	490	300	150	490	65	100	910	190	220	510	740	5,100
5	135-150	19	22	29	120	82	160	88	39	110	17	34	220	71	65	110	180	1,400
6-D	235-250	460	460	1,400	5,000	4,100	5,900	2,400	2,300	5,900	460	1,100	11,000	2,300	3,600	4,500	9,500	59,000
7-D	35-50	2,200	530	4,000	12,000	10,000	14,000	6,900	4,800	13,000	1,600	2,700	28,000	5,600	3,500	16,000	23,000	150,000
8	90-105	7	7	7	7	7	7	93	7	7	7	7	35	21	19	20	30	290
9-C	145-160	1,500	2,700	5,800	23,000	19,000	27,000	11,000	10,000	25,000	3,000	3,500	48,000	11,000	5,800	18,000	39,000	250,000
10-C	135-150	680	870	2,000	5,800	5,300	6,300	3,400	2,500	6,300	790	1,300	12,000	2,500	4,500	5,300	10,000	71,000
11-D	145-160	590	1,400	2,800	8,800	7,600	11,000	4,800	4,100	9,400	590	1,900	19,000	4,000	5,600	8,200	16,000	100,000
12	153-168	16	16	16	45	50	100	120	50	55	16	16	100	50	80	68	100	910
13	155-170	18	18	18	18	18	68	18	44	18	18	18	68	18	74	59	74	560
14	140-155	25	25	25	25	25	25	25	25	25	25	25	63	25	25	58	58	500
15-D	165-180	1,100	1,200	3,300	12,000	10,000	14,000	5,800	5,800	14,000	1,600	2,300	23,000	5,800	3,800	11,000	20,000	130,000
16	160-175	14	14	14	33	46	120	110	14	39	14	14	100	35	48	63	80	760
17-D	50-65	460	700	1,700	4,800	4,200	5,800	2,300	2,000	5,200	580	1,200	9,700	2,000	5,200	4,800	8,800	61,000
18	156-171	29	29	29	29	29	65	440	29	29	29	29	29	29	130	29	29	1,000
19	181-196	31	31	31	31	31	130	31	31	31	31	31	72	31	31	31	78	670
OMOEE SEL		NA	NA	370,000	1,480,000	1,440,000	NA	320,000	1,340,000	460,000	130,000	160,000	1,020,000	320,000	NA	950,000	850,000	10,000,000

NA = Not applicable
C = Results merged from two separate sample runs.
D = Analysis at a secondary dilution factor.

PAH Codes:

Acene = Acenaphthene
Aceny = Acenaphthylene
Anth = Anthracene
Bena = Benz(a)anthracene
Benap = Benzo(a)pyrene
Benb = Benzo(b)fluoroanthene
Beng = Benzo(g,h,i)perylene
Benk = Benzo(k)fluoroanthene
Chry = Chrysene
Diben = Dibenz(a,h)anthracene
Fluo = Fluorene
Flut = Fluoranthene
Indp = Indeno(1,2,3 - cd)pyrene
Naph = Naphthalene
Phen = Phenanthrene
Pyrn = Pyrene

Table 3-22. Total PCB Results for Selected Sites

Site Code	Core Depth (cm)	Replicate Type	Total PCBs (ng/g) (dry wt.)	Mean PCB Conc. (ng/g) (dry wt.)	Standard Deviation	% Organic Carbon	Total PCBs (ng/g OC) (dry wt.)
KMB 1	0-8		16.2			2.2	738
KMB 2	0-12		19.9			1.7	1170
KMB 3	0-15		64.9			3.1	2090
KMB 4	0-15		44.7			2.2	2030
KMB 5	0-15		60.1	63.5	4.80	2.8	2270
KMB 5	0-15	AR	66.9			2.8	2390
MNS 1	0-10		**259**			4	6480
MNS 2	0-12		**313**			4.8	6520
MNS 3	0-15		**270**			3.2	8440
MNS 4	0-15		**405**			3.5	11600
MNS 4	0-15(VC)		**148**			2.6	5690
MNS 5	0-10		**90.5**			2.4	3770
MNS 5	0-10	AR	**99.4**	95.0	6.29	2.4	3960
MNS 5	5-20 (VC)		55.4			1.6	3460
MNS 1	9-24		**119**			3.4	3500
MNS 2	15-30		**195**			3.8	5130
MNS 3	15-30		**581**			4.6	12600
MNS 4	15-30		64.4			1.9	3390
MNS 4	15-30	AR	**115**	89.7	35.8	1.9	4720
MNS 5	20-35		58.1			0.67	8670
MNS 1	24-39		**259**			4.2	6170
MNS 2	95-125		**75.0**			6.7	1120
MNS 3	30-45		**250**			4	6250
MNS 4	30-45		**87.6**			2.2	3980
MNS 5	35-50		**107**			2.9	3690
MNS 1	39-54		**496**			4.0	12400
MNS 2	145-160		50.9			4.6	1110
MNS 3	45-60		**113**			4.1	5140
STP 1	0-15		**78.6**			3.0	2620
STP 2	0-15		**74.5**			3.4	2190
STP 3	0-10		**109**			3.4	3210
STP 4	0-15		58.9			3.6	1640
STP 5	0-15		**155**			4.1	3780

Bold values exceed the OMOEE LEL value of 70 ng/g PCBs
AR = Analytical Replicate

Table 3-22. Continued

Site Code	Core Depth (cm)	Replicate Type	Total PCBs (ng/g) (dry wt.)	Mean PCB Conc. (ng/g) (dry wt.)	Standard Deviation	% Organic Carbon	Total PCBs (ng/g OC) (dry wt.)
STP 6	0-15		69.6			3.4	2050
STP 6	0-15	AR	64.7	67.2	3.46	3.4	1980
STP 7	0-15		**109**			3.2	3410
STP 8	0-15		**140**			5	2800
STP 10	0-10		**121**			3.4	3560
STP 12	0-10		**116**			4.1	2830
STP 1	15-30		**139**			4	3480
STP 2	10-25		**213**			4.5	4730
STP 3	15-30		35.6			3.9	913
STP 4	15-30		48.1			3.4	1420
STP 6	7-23		62.6			3.2	1960
STP 7	5-23		**99.7**			3.2	3120
STP 7	5-23	AR	**101**	100.4	0.919	3.2	3140
STP 8	15-30		**88.1**			5	1760
STP 8	15-30	AR	**86.3**	87.2	1.27	5	1740
STP 12	15-30		**549**			4.7	11700
STP 1	30-45		**145**			2.3	6300
STP 3	30-45		21.1			1.8	1170
STP 4	30-45		69.2			4.6	1500
STP 6	23-38		**81.5**			3.6	2260
STP 12	30-46		**353**			3.7	9540
STP 12	76-91		30.4			6.4	475
SUS 1	0-15		**220**			4.7	4681
SUS 1	0-15	AR	**190**	205	21.2	4.7	4040
SUS 2	0-15		**121**			3.5	3460
SUS 3	0-15		**326**			4.9	6650
SUS 4	0-15		**132**			4.3	3070
SUS 5	0-15		**134**			2.3	5830
SUS 6	0-15		**95.0**			1.9	5000
SUS 7	0-5		**102**			2.7	3780

Bold values exceed the OMOEE LEL value of 70 ng/g PCBs
AR = Analytical Replicate

Table 3-22. Continued

Site Code	Core Depth (cm)	Replicate Type	Total PCBs (ng/g) (dry wt.)	Mean PCB Conc. (ng/g) (dry wt.)	Standard Deviation	% Organic Carbon	Total PCBs (ng/g OC) (dry wt.)
SUS 1	15-30		**535**			19	2820
SUS 2	15-30		**410**			19	2160
SUS 3	15-30		**131**			4.8	2730
SUS 4	15-30		**315**			2.8	11300
SUS 5	15-23		**1140**			0.83	137000
SUS 6	15-30		44.4			0.33	13500
SUS 7	15-30		**97.4**			3	3250
SUS 1	30-45		**295**			15	1970
SUS 2	30-45		**275**			11	2500
SUS 3	30-45		**88.1**			3.6	2447
SUS 3	30-45	AR	**83.6**	85.9	3.18	3.6	2380
SUS 4	30-45		**259**			4.3	6020
SUS 5	24-38		65.0			0.80	8120
SUS 6	30-45		57.9			0.28	20700
SUS 7	30-45		57.6			1.4	4110
SUS 1	145-160		43.7			1.4	3120
SUS 2	111-126		**98.1**			2.7	3630
SUS 3	140-155		20.8			3.1	671
SUS 4	100-115		**106**			3.2	3310
SUS 5	39-54		**120**			2.4	5000
SUS 6	115-130		55.3			1.1	5030
SUS 7	63-78		14.1			0.29	4860
WLS 1	0-15		**145**			2.9	5000
WLS 2	0-15		**120**			2.3	5220
WLS 3	0-17		**241**			3.1	7770
WLS 4	0-20		**283**			3	9430
WLS 5	0-18		**491**			4.9	10000
WLS 6	0-15		**203**			3.7	6490
WLS 7	0-15		**205**			3.5	5860
WLS 8	0-15		**822**			4.5	18300
WLS 8	0-15	AR	**732**	777	63.6	4.5	17300
WLS 9	0-20		**301**			3.8	7920
WLS 10	0-15		**112**			1.7	6590
WLS 11	0-20		**150**			3.6	4170
WLS 12	0-19		**396**			4.9	8080

Bold values exceed the OMOEE LEL value of 70 ng/g PCBs
AR = Analytical Replicate

Table 3-22. Continued

Site Code	Core Depth (cm)	Replicate Type	Total PCBs (ng/g) (dry wt.)	Mean PCB Conc. (ng/g) (dry wt.)	Standard Deviation	% Organic Carbon	Total PCBs (ng/g OC) (dry wt.)
WLS 13	0-18		**491**			4.7	10400
WLS 14	0-15		**346**			5.6	6180
WLS 15	0-5		**366**			2.6	14100
WLS 16	0-18		**424**			4.7	9020
WLS 17	0-5		**215**			2.8	7680
WLS 18	0-15		**94.3**			2.7	3490
WLS 18	0-15	AR	**93.6**	94.0	0.495	2.7	3480
WLS 19	0-20		**271**			4.4	6160
WLS 1	15-30		**590**			3.3	1790
WLS 2	15-30		13.8			1	1380
WLS 3	15-30		**117**			3.5	3340
WLS 4	15-30		40.5			1.1	3680
WLS 5	15-30		**422**			8.7	4850
WLS 5	15-30	AR	**460**	441	26.9	8.7	5070
WLS 6	15-30		**571**			2.8	20400
WLS 7	5-20		**679**			3.7	18400
WLS 8	15-30		4.40			3.9	113
WLS 9	15-30	No Data Available					
WLS 10	15-30		21.3			2.6	819
WLS 11	15-30		**535**			4.2	12700
WLS 12	15-30		**77.2**			3.5	2210
WLS 13	15-30		**876**			4.3	20400
WLS 14	15-30		14.6			2.3	635
WLS 15	15-30		10.8			1.8	600
WLS 16	15-30		**463**			3.7	12500
WLS 17	15-30		44.0			3	1470
WLS 17	15-30	AR	42.9	43.5	0.778	3	1450
WLS 18	15-30		14.1			1.9	742
WLS 19	15-30		18.2			2.7	674
WLS 1	30-45		**1220**			3.3	37000
WLS 2	30-45		15.3			1	1530
WLS 2	30-45	AR	23.8	19.6	6.01	1	1960
WLS 3	30-45		**435**			4.5	9670
WLS 4	30-45		39.0			0.76	5130

Bold values exceed the OMOEE LEL value of 70 ng/g PCBs
AR = Analytical Replicate

Table 3-22. Continued

Site Code	Core Depth (cm)	Replicate Type	Total PCBs (ng/g) (dry wt.)	Mean PCB Conc. (ng/g) (dry wt.)	Standard Deviation	% Organic Carbon	Total PCBs (ng/g OC) (dry wt.)
WLS 5	30-45		61.9			27	229
WLS 6	30-45		**453**			3.6	12600
WLS 7	20-35		**168**			1.4	12000
WLS 8	30-45		63.2			5.8	1090
WLS 9	30-45		**700**			3.1	22600
WLS 10	30-45		**167**			0.79	21100
WLS 11	30-45		**727**			3.5	20800
WLS 11	30-45	AR	**740**	734	9.19	3.5	21000
WLS 12	30-45		**1270**			5	25400
WLS 13	30-45		**74.2**			6.8	1090
WLS 14	30-45		31.4			3.5	897
WLS 15	30-45		26.8			3.9	687
WLS 16	30-45		**740**			6.9	10700
WLS 17	30-45		58.7			2.8	2100
WLS 18	30-45		19.3			1.5	1290
WLS 19	30-45		30.5			2.7	1130
WLS 1	189-204		**90.6**			3.7	2450
WLS 2	167-182		**78.7**			5.2	1510
WLS 3	173-188		50.4			6.1	826
WLS 3	173-188	AR	40.8	45.6	6.79	6.1	748
WLS 4	105-120		27.9			4.3	649
WLS 5	135-150		45.5			17	268
WLS 6	235-250		65.5			2.2	2980
WLS 6	235-250	AR	**71.4**	68.5	4.17	2.2	3110
WLS 7	35-50		46.1			1.6	2880
WLS 8	90-105		49.9			27	185
WLS 9	145-160		**515**			3.1	16600
WLS 10	135-150		14.5			0.38	3820
WLS 11	145-160		54.7			1.7	3220
WLS 12	153-168		22.1			4.4	502
WLS 12	153-168	AR	14.1	18.1	5.66	4.4	411
WLS 13	155-170		35.4			3.4	1040
WLS 14	140-155		26.9			2.4	1120
WLS 15	165-180		33.0			2.6	1270
WLS 16	160-175		24.2			4.6	526
WLS 17	50-65		37.5			3.3	1140
WLS 18	156-171		23.2			1.7	1370
WLS 19	181-196		40.0			1.8	2220

Bold values exceed the OMOEE LEL value of 70 ng/g PCBs
AR = Analytical Replicate

Table 3-23. Subset of Seven PCB Congeners

IUPAC Number	Congener Name
6	2,3’ dichlorobiphenyl
18	2,2’,5 trichlorobiphenyl
52	2,2’,5,5’ tetrachlorobiphenyl
101	2,2’,4,5,5’ pentachlorobiphenyl
128	2’,3,3’,4,4’ hexachlorobiphenyl
180	2,2’,3,4,4’,5,5’ heptachlorobiphenyl
201	2,2’,3,3’,4,5,5’,6’ octachlorobiphenyl

Table 3-24. Results for Seven PCB Congeners at Selected Sites

Site Code	Core Depth (cm)	Replicate Type	PCB Congener Number (ng/g OC)						
			6	18	52	101	128	180	201
KMB 1	0-8		-	12.9	22.4	40.9	-	3.26	4.60
KMB 2	0-12		3.86	10.2	22.4	58.5*	-	36.1	9.7
KMB 3	0-15		2.51	27.4	70.2	88.6	19.5	61.8	16.1
KMB 4	0-15		23.8	25.7	53.8	97.7	10.7	70.7	16.2
KMB 5	0-15		20.3	19.2	45.0	125	14.2	78.4	17.6
KMB 5	0-15	AR	25.4	32.1	46.1	112	22.6	95.2	24.7
MNS 1	0-10		5.00	256*	1830*	203	76.5	91.5	22.5
MNS 2	0-12		0.75	106	1380*	182	89.0	112	28.0
MNS 3	0-15		4.79	100	1420*	355	114	198	49.8
MNS 4	0-15		12.2	162	990*	614	157	239	82.8
MNS 4	0-15(VC)		3.63	66.5*	84.2	146	25.4	44.5	22.0
MNS 5	0-10		15.1	118	80.9	171	43.6	83	33.8
MNS 5	0-10	AR	24.9	102	84.1	177	50.1	106	43.5
MNS 5	5-20 (VC)		95.4	41.6	88.8	95.4	41.2	30.4	13.1
MNS 1	9-24		-	56.6	-	199	56.2	68.7	15.9
MNS 2	15-30		-	128	159	306	70.8	89.5	30.9
MNS 3	15-30		19.5	268	462	764*	-	178	54.5
MNS 4	15-30		-	32.9	92.1	139	16.2	45.8	14.5
MNS 4	15-30	AR	49.7	14.9	45.6	243	-	39.4	37.9
MNS 5	20-35		380.05	50.4	280	287	69.9	53.3	79.4
MNS 1	24-39		11.2	-	158	417	78.0	102	30.5
MNS 2	95-125		-	-	9.6	25.0	2.64	37.7	20.3
MNS 3	30-45		7.07	330	203	284	57.7	95.3	39.4
MNS 4	30-45		-	517	124	235	48.2	64.0	23.1
MNS 5	35-50		146	237	167	92.4	55.2	21.1	11.3
MNS 1	39-54		29.6	166	348	702*	176	179	54.7
MNS 2	145-160		65.3	117*	24.2	8.82	-	-	-
MNS 3	45-60		-	178	39.2	106	77.1	125	75.9
STP 1	0-15		-	65.2	78.0	132	18.7	59.6	16.5
STP 2	0-15		-	34.9	51.1	106	19.9	41.5	14.0
STP 3	0-10		-	38.9	105	126	25.4	43.7	16.0
STP 4	0-15		2.49	17.6	46.8	87.4	13.8	27.1	9.34
STP 5	0-15		-	49.4	110	210	46.7	83.5	26.5
STP 6	0-15		-	42.4	64.6	83.2	15.0	30.8	13.9
STP 6	0-15	AR	6.24	64.4	58.9	85.8	13.0	29.4	12.2

AR = Analytical replicate
* = Congeners eliminated by COMSTAR
- = Sample either below the detection limit or not quantifiable

Table 3-24. Continued

Site Code	Core Depth (cm)	Replicate Type	PCB Congener Number (ng/g OC)						
			6	18	52	101	128	180	201
STP 7	0-15		-	65.1	93.6	169	30.0	57.9	19.6
STP 8	0-15		-	40.7	97.4	120	36.1	57.3	24.2
STP 10	0-10		-	128	111	170	39.1	73.4	24.6
STP 12	0-10		-	36.6	85.7	165	40.7	65.3	19.1
STP 1	15-30		-	64.7	129	187	37.1	70.5	20.3
STP 2	10-25		-	51.9	167	254	60.3	97.4	32.8
STP 3	15-30		18.8	80.4	33.7	8.94	3.35	5.68	7.60
STP 4	15-30		8.50	51.4	54.4	64.1	14.7	19.2	8.12
STP 6	7-23		-	56.3	79.1	88.4	20.5	30.4	16.1
STP 7	5-23		-	59.8	91.2	149	36.9	55.4	27.1
STP 7	5-23	AR	-	76.1	90.9	151	37.5	54.2	24.3
STP 8	15-30		-	35.1	66.7	59.5	16.1	26.1	15.2
STP 8	15-30	AR	-	45.3	67.0	57.6	16.5	25.6	15.6
STP 12	15-30		29.3	221	401	680	118	250	62.4
STP 1	30-45		8.83	105	231	375	76.7	106	34.5
STP 3	30-45		7.97	140	62.0	25.3	5.42	2.67	7.68
STP 4	30-45		-	46.6	43.8	65.8	12.8	22.2	11.3
STP 6	23-38		-	62.3	67.0	109	20.9	37.5	15.4
STP 12	30-46		9.63	138	299	519	99.4	161	111
STP 12	76-91		1.96	51.9 *	7.6	10.4	2.88	3.08	3.06
SUS 1	0-15		-	346 *	153	222	50.3	108	29.2
SUS 1	0-15	AR	-	229 *	140	179	35.1	110	28.6
SUS 2	0-15		-	177	113	175	46.6	106	27.2
SUS 3	0-15		-	61.4	295	299	75.6	135	5.10
SUS 4	0-15		5.61	80.5	118	154	45.5	42.8	22.0
SUS 5	0-15		2.85	184	201	306	60.2	104	32.2
SUS 6	0-15		4.71	168	184	255	42.0	97.3	33.0
SUS 7	0-5		0.74	135	156	177	19.5	65.9	22.7
SUS 1	15-30		0.39	40.0	85.2	131 *	32.6	61.6	11.8
SUS 2	15-30		1.00	26.4	60.7	92.4	28.0	42.8	9.88
SUS 3	15-30		-	73.7	-	93.2	48.8	56.0	15.3
SUS 4	15-30		5.75	110	378	501	129	179	40.4
SUS 5	15-23		5.86	88.9	6250	9378	2680	1510	148
SUS 6	15-30		-	96.2	690	802	79.0	150	47.4
SUS 7	15-30		-	54.7	76.3	121	30.9	60.1	20.0
SUS 1	30-45		-	46.3	45.3	97.7	25.4	53.1	14.1
SUS 2	30-45		-	95.1 *	87.9	134	43.8	60.9	0.273
SUS 3	30-45		-	64.2 *	2.7	4.93	2.42	5.56	1.59

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- = Sample either below the detection limit or not quantifiable

Table 3-24. Continued

Site Code	Core Depth (cm)	Replicate Type	PCB Congener Number (ng/g OC)						
			6	18	52	101	128	180	201
SUS 3	30-45	AR	2.57	125 *	41.5	73.8	23.9	79.3	21.3
SUS 4	30-45		-	175	24.9	270	75.7	146	32.2
SUS 5	24-38		-	128	374	456	51.1	124	36.7
SUS 6	30-45		8.90	551	1010	1337	68.3	188	57.1
SUS 7	30-45		0.93	239	151	189	6.66	77.2	36.1
SUS 1	145-160		-	158	127	197	121	148	35.4
SUS 2	111-126		-	88.5	145	196	39.0	62.1	12.7
SUS 3	140-155		-	54.6	53.8	64.6	16.7	17.0	8.09
SUS 3	140-155	AR	-	12.6	18.1	18.4	-	3.54	1.70
SUS 4	100-115		-	32.9	40.8	34.0	9.27	28.7	11.3
SUS 5	39-54		-	117	118	167 *	45.2	86.2	29.4
SUS 6	115-130		13.6	172	95.5	76.7	-	-	-
SUS 7	63-78		-	216	327	287	-	-	-
WLS 1	0-15		2.80	80.5	148	306	45.0	122	29.1
WLS 2	0-15		4.77	77.8	181	358	43.9	115	28.6
WLS 3	0-17		4.63	90.6	258	468	45.6	213	44.1
WLS 4	0-20		11.6	117	329	656 *	66.5	235	57.9
WLS 5	0-18		-	117	380	578	101	218	60.1
WLS 6	0-15		10.3	64.4	195	272	47.8	146	32.6
WLS 7	0-15		8.79	64.6	203	319	52.7	149	32.5
WLS 8	0-15		19.4	263	708	1070 *	197	290	84.0
WLS 8	0-15	AR	17.9	302	705	1140 *	173	253	75.5
WLS 9	0-20		6.59	144	340	430	55.7	172	35.4
WLS 10	0-15		4.18	74.5	242	325	48.7	155	41.4
WLS 11	0-20		7.63	64.8	158	225	39.2	103	28.3
WLS 12	0-19		11.4	112	348	473	92.6	139	39.1
WLS 13	0-18		14.1	125	473	631	104	177	49.0
WLS 14	0-15		7.13	99.6	265	423	61.7	102	29.9
WLS 15	0-5		12.3	204	653	797	125	238	61.8
WLS 16	0-18		12.9	126	412	529	102	160	43.5
WLS 17	0-5		5.26	102	325	443	63.1	138	42.6
WLS 18	0-15		5.21	49.4	134	204	21.5	64.1	16.6
WLS 18	0-15	AR	1.66	42.2	137	213	23.1	66.9	16.7
WLS 19	0-20		12.2	69.5	241	524 *	28.1	100	37.1
WLS 1	15-30		26.8	275	534	1340 *	121	544	133
WLS 2	15-30		-	14.1	29.8	53.9 *	-	8.24	1.56

AR = Analytical replicate
* = Congeners eliminated by COMSTAR
- = Sample either below the detection limit or not quantifiable

Table 3-24. Continued

Site Code	Core Depth (cm)	Replicate Type	PCB Congener Number (ng/g OC)						
			6	18	52	101	128	180	201
WLS 3	15-30		10.6	33.2	77.5 *	237 *	9.52	82.7	24.7
WLS 4	15-30		-	14.6	200	244	-	86.0	21.2
WLS 5	15-30		9.85	20.6	132	351	37.5	92.8	32.8
WLS 5	15-30	AR	6.86	94.8	156	231	85.4	96.8	37.6
WLS 6	15-30		56.1	292	860	1470 *	135	435	111
WLS 7	5-20		39.4	283	764	1200	55.3	416	110
WLS 8	15-30		-	2.80	4.6	7.36 *	-	-	-
WLS 8	15-30	AR	-	3.89	6.5 *	6.40 *	-	-	-
WLS 9	15-30		No Data Available						
WLS 10	15-30		3.23	7.10	22.4 *	55.9 *	4.36	14.3	3.64
WLS 11	15-30		18.2	207	503	630	106	322	82.7
WLS 12	15-30		-	37.2	80.6	125 *	6.55	43.1	13.2
WLS 13	15-30		113	158	816	1390	239	339	132
WLS 14	15-30		3.06	22.0	27.8	42.2 *	-	-	-
WLS 15	15-30		3.16	25.5	24.9	40.2 *	-	0.73	0.57
WLS 16	15-30		31.1	150	571	909	146	229	76.9
WLS 17	15-30		-	26.8	33.7	85.9 *	-	28.8	7.08
WLS 17	15-30	AR	-	23.8	34.4	83.8 *	-	27.8	6.75
WLS 18	15-30		2.14	27.2	26.5	53.5 *	-	3.69	-
WLS 19	15-30		2.85	4.40	23.4	39.1 *	-	5.34	3.32
WLS 1	30-45		78.5	748	886	1720 *	283	1280	288
WLS 2	30-45		5.00	124	74.0	85.0	-	-	2.00
WLS 2	30-45	AR	7.00	529	63.0	79.0	-	6.00	4.00
WLS 3	30-45		8.40	458	396	592	97.9	182	75.2
WLS 4	30-45		-	141	205	286	18.2	73.4	30.7
WLS 5	30-45		2.09	78.59 *	4.9	3.35	0.63	1.30	0.54
WLS 6	30-45		22.7	291	509	601	65.3	282	81.8
WLS 7	20-35		29.3	317	443	693 *	70.9	270	84.2
WLS 8	30-45		11.2	468 *	25.8	19.3	6.84	-	0.386
WLS 9	30-45		15.2	493	1000.0	1230	139	400	107
WLS 10	30-45		-	5840	184.8	211	43.9	53.6	11.2
WLS 11	30-45		26.2	769	1110	733	67.9	240	73.1

AR = Analytical replicate
* = Congeners eliminated by COMSTAR
- = Sample either below the detection limit or not quantifiable

Table 3-24. Continued

Site Code	Core Depth (cm)	Replicate Type	PCB Congener Number (ng/g OC)						
			6	18	52	101	128	180	201
WLS 11	30-45	AR	27.6	782	1110	801	72.6	236	71.4
WLS 12	30-45		16.4	344	1050	1860	294	411	155
WLS 13	30-45		1.37	47.5 *	12.6	16.1	24.3	25.2	14.4
WLS 14	30-45		5.69	226 *	39.7	28.7	3.47	-	-
WLS 15	30-45		14.6	71.7	25.4	19.4	6.10	-	1.96
WLS 16	30-45		3.30	234	453	750	128	176	81.3
WLS 17	30-45		-	501 *	68.8	50.8	11.6	28.5	4.29
WLS 18	30-45		5.33	103	71.1	76.5 *	1.39	-	-
WLS 19	30-45		0.76	89.9	50.3	45.2	2.55	-	-
WLS 1	189-204		1.35	82.2	94.3	135	18.4	36.2	13.0
WLS 2	167-182		1.73	173 *	46.0	70.6	8.46	20.0	7.50
WLS 3	173-188		3.44	315 *	22.3	19.5	-	-	-
WLS 3	173-188	AR	4.43	179 *	23.8	22.5	-	-	-
WLS 4	105-120		1.63	137 *	18.4	22.6	5.35	-	0.233
WLS 5	135-150		1.24	40.1 *	8.0	8.24	-	-	0.71
WLS 6	235-250		2.27	116	101	169	19.1	43.6	12.3
WLS 6	235-250	AR	2.73	85.9	122	164	15.9	71.4	20.0
WLS 7	35-50		3.13	45.0	98.8	145	24.4	59.4	18.8
WLS 8	90-105		1.41	36.1 *	7.9	6.15	-	-	0.148
WLS 9	145-160		35.5	185	502	962 *	0.000	368	69.4
WLS 10	135-150		10.5	94.7	139	197	10.5	18.4	15.8
WLS 11	145-160		5.88	59.4	92.9	155	20.0	48.8	11.2
WLS 12	153-168		1.59	142 *	10.5	11.6	0.455	-	-
WLS 12	153-168	AR	2.50	45.7	13.9	12.7	1.14	-	0.227
WLS 13	155-170		1.47	238 *	11.2	14.7	-	-	0.59
WLS 14	140-155		2.08	465 *	10.8	14.6	-	-	-
WLS 15	165-180		-	71.2	15.0	23.5	30.8	33.8	19.6
WLS 16	160-175		1.30	187 *	10.2	8.91	-	-	-
WLS 17	50-65		-	131 *	38.2	46.7	1.52	15.8	4.55
WLS 18	156-171		4.12	474 *	14.7	21.2	-	-	-
WLS 19	181-196		2.22	796 *	18.3	20.0	-	-	-

AR = Analytical replicate
* = Congeners eliminated by COMSTAR
- = Sample either below the detection limit or not quantifiable

Table 3-25. Mean Survival (%) of *H. azteca* and *C. tentans* Exposed to Test Sediments

	Mean Survival (%)	
Sample #	*H. azteca*	*C. tentans*
DMIR 01	70*	72*
DMIR 02	95	88
DMIR 03	82	72
DMIR 04	98	75
ERP 01	67	78
ERP 02	58*	90
ERP 03	80	60
HOB 07	96	60
HOB 08	100	28
HOB 10	95	80
HOB 11	68	70
HOB 12	55*	70
HOB 13	52*	72
HOB 14	85	80
HOB 15	78	80
KMB 04	78	48
KMB 05	80	65
MLH 01	75	75
MLH 02	80	70
MLH 03	90	70
MLH 04	65*	72
MLH 05	82	82
MLH 06	92	92
MNS 01	89	28
MNS 03	100	30
STP 01	79	58
STP 03	80	62
STP 04	96	65
STP 06	50	68
STP 07	68	68
SUS 01	85	72
SUS 03	92	55*
SUS 05	96	40
SUS 07	45	0
WLS 01	85	68*
WLS 02	90	90

	Mean Survival (%)	
Sample #	*H. azteca*	*C. tentans*
WLS 03	72	80
WLS 04	98	78
WLS 06	90	80
WLS 08	90	80
WLS 12	96	58
WLS 13	96	45
WLS 14	96	50
WLS 16	93	42

*Mean survival significantly less than control survival at p = 0.05.
Shaded values indicate unacceptable contol survival.

Table 3-26. Normalized Survival (%) of *H. azteca* and *C. tentans* Exposed to Test Sediments

	Normalized Survival (%)	
Sample #	*H. azteca*	*C. tentans*
DMIR 01	76*	76*
DMIR 02	103	93
DMIR 03	93	88
DMIR 04	111	91
ERP 01	73	92
ERP 02	63*	106
ERP 03	103	88
HOB 07	108	115
HOB 08	112	54
HOB 10	108	91
HOB 11	77	80
HOB 12	63*	80
HOB 13	59*	82
HOB 14	97	91
HOB 15	89	91
KMB 04	100	71
KMB 05	103	96
MLH 01	85	91
MLH 02	91	85
MLH 03	102	85
MLH 04	74*	88
MLH 05	93	100
MLH 06	100	97
MNS 01	100	54
MNS 03	112	58
STP 01	89	112
STP 03	87	73
STP 04	108	125
STP 06	64	100
STP 07	87	100
SUS 01	92	76
SUS 03	100	58*
SUS 05	108	77

	Normalized Survival (%)	
Sample #	*H. azteca*	*C. tentans*
SUS 07	58	0
WLS 01	92	72*
WLS 02	98	95
WLS 03	78	84
WLS 04	107	82
WLS 06	98	84
WLS 08	98	84
WLS 12	108	112
WLS 13	108	87
WLS 14	108	96
WLS 16	104	81

*Mean survival significantly less than control survival at p = 0.05.
Shaded values indicate unacceptable contol survival.

Table 3-27. Mean Total Abundance (individuals/m^2) and Taxa Richness Values for the Benthological Community Survey

Site	# of Replicates	Mean Total Abundance	SD*	Mean Taxa Richness	SD*
DMIR 1	1	215	149	3	2
DMIR 2	1	1,120	637	6	2
DMIR 3	1	804	813	7	6
DMIR 4	1	2,986	1,318	18	5
ERP 1	3	7,640	1,998	11	2
ERP 2	3	6,311	2,233	13	3
ERP 3	3	14,283	5,887	17	5
ERP 5	3	4,900	1,007	7	3
HOB 1	3	3,238	1,556	6	2
HOB 2	3	7,308	4,245	11	4
HOB 3	3	11,751	12,697	10	6
HOB 4	3	7,100	4,758	9	2
HOB 5	3	9,135	3,102	10	2
HOB 6	3	3,737	1,318	8	3
HOB 7	3	15,114	3,462	15	1
HOB 8	2	249	249	1	1
HOB 9	2	249	249	1	1
HOB 10	3	2,740	1,556	6	3
HOB 11	3	2,865	778	6	1
HOB 12	3	3,073	1,416	7	3
HOB 13	3	6,975	2,215	10	0
HOB 14	3	8,221	4,244	9	4
HOB 15	3	4,484	1,515	10	3
KMB 1	3	2,325	1,767	4	1
KMB 2	3	1,578	943	4	2

*SD = standard deviation

Table 3-27. Continued

Site	# of Replicates	Mean Total Abundance	SD*	Mean Taxa Richness	SD*
KMB 3	3	4,734	2,157	8	1
KMB 4	3	2,408	380	3	0
KMB 5	3	2,491	1,977	3	2
MLH 1	3	9,965	3,835	7	1
MLH 2	3	8,968	4,485	8	2
MLH 3	3	3,986	2,625	4	3
MLH 4	3	2,491	1,726	2	1
MLH 5	3	3,737	2,589	4	2
MLH 6	3	6,228	4,315	4	2
MLH 7	3	4,733	2,625	2	1
MLH 8	3	3,737	1,495	4	1
MLH 9	3	4,484	3,955	4	2
MLH 10	3	10,214	4,379	5	4
MNS 1	3	30,643	2,377	9	2
MNS 2	3	57,051	2,129	14	3
MNS 3	3	32,138	13,133	13	2
MNS 4	3	20,429	7,029	12	3
MNS 5	3	15,612	5,775	14	3
STP 1	3	6,726	6,014	9	6
STP 2	3	15,695	2,451	13	1
STP 3	3	5,813	5,107	9	6
STP 4	3	2,367	1,079	5	2
STP 5	3	1,370	1,142	3	3
STP 6	3	2,865	2,253	3	1
STP 7	3	3,363	1,495	5	1
STP 8	3	623	216	2	1

*SD = standard deviation

Table 3-27. Continued

Site	# of Replicates	Mean Total Abundance	SD*	Mean Taxa Richness	SD*
STP 10	3	1,993	249	7	2
STP 12	3	7,225	3,770	9	1
SUS 1	3	27,279	7,502	10	10
SUS 2	3	45,839	20,611	13	3
SUS 3	3	25,411	4,546	13	1
SUS 4	3	45,092	6,740	13	1
SUS 5	3	14,449	8,121	10	3
SUS 6	3	2,118	1,415	3	1
SUS 7	3	5,605	1,713	7	1
SUS 8	1	7,848	--	10	--
WLS 1	3	2,989	747	3	1
WLS 2	3	1,121	647	2	1
WLS 3	3	8,636	4,245	7	2
WLS 4	3	7,349	431	5	2
WLS 5	3	8,096	1,556	6	2
WLS 6	3	23,293	12,713	12	2
WLS 7	3	22,048	6,981	9	2
WLS 8	3	24,041	3,178	13	1
WLS 9	3	34,379	9,908	13	2
WLS 10	3	17,190	4,592	9	2
WLS 11	3	21,301	7,130	10	1
WLS 12	3	34,006	15,239	9	2
WLS 13	3	38,116	19,572	13	1
WLS 14	3	14,823	5,745	11	4
WLS 15	3	15,321	10,772	8	4
WLS 16	3	25,037	8,898	10	3

*SD = standard deviation

Table 3-27. Continued

Site	# of Replicates	Mean Total Abundance	SD*	Mean Taxa Richness	SD*
WLS 17	3	36,041	18,657	15	2
WLS 18	3	11,460	2,403	6	2
WLS 19	3	14,699	4,427	9	1

*SD = standard deviation

Table 3-28. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the DMIR Sites (n=3)

Taxon	DMIR 1	DMIR 2	DMIR 3	DMIR 4
Tubificidae	158 (90) 73%	919 (585) 82%	632 (151) 79%	1765 (807) 59%
Naididae	-	-	-	Less 1%
Polychaeta	-	-	14 (25) 2%	100 (25) 3%
Nematoda	14 (25) 7%	-	-	2%
Turbellaria	-	3%	-	-
Bivalvia	14 (25) 7%	158 (90) 14%	100 (25) 12%	273 (108) 9%
Gastropoda	-	-	-	-
Hydrachnida	-	-	-	-
Chironomidae	14 (25) 7%	14 (25) 1%	43 (75) 5%	646 (258) 22%
Chaoboridae	14 (25) 7%	-	-	76 (66) 2%
Ephemeroptera	-	-	2%	-
Trichoptera	-	-	-	1%
miscellaneous	-	-	-	1%

Table 3-29. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the ERP Sites (n=3)

Taxon	ERP 1	ERP 2	ERP 3	ERP 5
Tubificidae	2907 (288) 38%	332 (381) 5%	4235 (3670) 30%	1661 (381) 34%
Naididae	-	2076 (627) 33%	1578 (381) 11%	415 (519) 8%
Polychaeta	249 (249) 3%	-	2408 (801) 17%	1993 (659) 41%
Nematoda	1163 (1372) 15%	249 (249) 4%	1080 (575) 8%	-
Turbellaria	2%	-	498 (432) 3%	-
Bivalvia	1661 (144) 2%	166 (288) 3%	498 (659) 3%	83 (144) 3%
Gastropoda	-	1%	1%	-
Hydrachnida	332 (288) 4%	-	1%	2%
Chironomidae	2491 (498) 33%	3073 (875) 49%	3654 (2014) 26%	581 (381) 12%
Chaoboridae	-	-	-	-
Ephemeroptera	-	-	1%	-
Trichoptera	1%	166 (144) 3%	-	-
miscellaneous	1%	3%	1%	-

Table 3-30. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the HOB Sites (n=3)

Taxon	HOB 1	HOB 2	HOB 3	HOB 4	HOB 5	HOB 6	HOB 7	HOB 8
Tubificidae	1827 (875) 56%	3239 (2625) 44%	7474 (8084) 63%	3986 (3391) 57%	4609 (778) 50%	747 (659) 20%	8221 (3193) 54%	-
Naididae	249 (432) 8%	249 (432) 3%	1744 (1510) 15%	-	249 (432) 3%	-	997 (778) 7%	-
Polychaeta	332 (575) 10%	830 (761) 11%	166 (144) 2%	249 (249) 5%	166 (288) 3%	-	166 (144) 2%	-
Nematoda	-	249 (249) 3%	498 (863) 4%	623 (778) 9%	1%	332 (381) 9%	872 (571) 6%	-
Turbellaria	-	-	-	2%	1%	-	2%	-
Bivalvia	-	1412 (801) 19%	374 (647) 3%	623 (432) 9%	997 (432) 11%	83 (144) 2%	374 (0) 2%	83 (144) 33%
Gastropoda	3%	1%	2%	-	-	4%	2%	-
Hydrachnida	5%	1%	-	7%	1%	2%	2%	-
Chironomidae	498 (249) 15%	913 (519) 13%	747 (989) 6%	623 (216) 9%	1868 (1121) 20%	1744 (498) 47%	2367 (432) 16%	83 (144) 33%
Chaoboridae	83 (144) 3%	249 (249) 3%	498 (571) 5%	125 (216) 2%	872 (940) 9%	-	1121 (0) 7%	83 (144) 33%
Ephemeroptera	-	-	-	249 (432) 4%	-	249 (0) 7%	- -	-
Trichoptera	-	-	-	-	-	332 (575) 9%	- -	- -
miscellaneous	-	-	-	-	-	-	-	-

Table 3-30. Continued

Taxon	HOB 9	HOB 10	HOB 11	HOB 12	HOB 13	HOB 14	HOB 15
Tubificidae	-	830 (1229) 30%	1495 (647) 52%	830 (801) 27%	4401 (1007) 63%	5481 (2903) 67%	1910 (1007) 43%
Naididae	-	-	-	-	-	-	-
Polychaeta	-	-	-	249 (249) 8%	166 (144) 2%	249 (216) 3%	166 (288) 4%
Nematoda	-	-	374 (374) 13%	332 (381) 11%	249 (249) 4%	747 (747) 9%	498 (498) 11%
Turbellaria	-	-	4%	-	1%	-	249 (249) 6%
Bivalvia	-	747(249) 27%	498 (216) 17%	83 (144) 3%	913 (943) 13%	-	415 (381) 9%
Gastropoda	-	-	-	5%	1%	2%	4%
Hydrachnida	-	-	-	3%	1%	3%	2%
Chironomidae	83 (144) 33%	913 (627) 33%	249 (216) 9%	249 (0) 8%	415 (519) 6%	498 (432) 6%	997 (498) 22%
Chaoboridae	166 (144) 66%	83 (144) 3%	125 (216) 4%	747 (249) 24%	415 (144) 5%	249 (432) 3%	-
Ephemeroptera	-	83 (144) 3%	-	166 (288) 5%	-	374 (374) 5%	-
Trichoptera	-	83 (144) 3%	-	83 (144) 3%	1%	249 (216) 3%	-
miscellaneous	-	-	-	3%	2%	-	-

Table 3-31. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the KMB Sites (n=3)

Taxon	KMB 1	KMB 2	KMB 3	KMB 4	KMB 5
Tubificidae	498 (432) 21%	166 (288) 11%	1495 (898) 32%	664 (381) 28%	581 (144) 23%
Naididae	581 (1007) 25%	-	-	-	-
Polychaeta	581 (381) 25%	166 (288) 11%	1246 (863) 26%	-	-
Nematoda	166 (288) 7%	249 (249) 16%	-	-	-
Turbellaria	-	-	-	-	-
Bivalvia	-	415 (381) 26%	249 (249) 5%	83 (144) 3%	-
Gastropoda	3%	-	2%	-	-
Hydrachnida	-	-	249 (249) 5%	-	-
Chironomidae	249 (432) 11%	332 (144) 21%	1163 (144) 25%	83 (144) 3%	-
Chaoboridae	-	249 (249) 16%	249 (249) 5%	1578 (627) 66%	1827 (1696) 73%
Ephemeroptera	83 (144) 4%	-	-	-	-
Trichoptera	83 (144) 4%	-	-	-	-
miscellaneous	-	-	-	-	3%

Table 3-32. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the MLH Sites (n=3)

Taxon	MLH 1	MLH 2	MLH 3	MLH 4	MLH 5	MLH 6	MLH 7	MLH 8	MLH 9	MLH 10
Tubificidae	5730 (3021) 58%	3737 (1295) 42%	2740 (1556) 69%	249 (432) 10%	498 (432) 13%	498 (432) 8%	-	747 (0) 20%	747 (747) 17%	5481 (1881) 55%
Naididae	-	997 (432) 11%	-	-	-	249 (432) 4%	-	-	-	-
Polychaeta	997 (432) 10%	498 (863) 6%	-	1246 (1556) 50%	1495 (1495) 40%	3488 (3452) 56%	3737 (2242) 79%	1246 (1142) 33%	2491 (3021) 56%	2491 (2402) 25%
Nematoda	1246 (1556) 13%	997 (1142) 11%	6%	498 (432) 20%	-	4%	-	7%	6%	2%
Turbellaria	-	-	-	-	-	-	-	-	-	-
Bivalvia	498 (432) 5%	747 (747) 8%	-	-	-	498 (432) 8%	249 (432) 5%	249 (432) 7%	498 (432) 11%	498 (863) 5%
Gastropoda	-	249 (432) 3%	-	-	-	249 (432) 4%	249 (432) 5%	249 (432) 7%	249 (432) 6%	-
Hydrachnida	-	-	-	-	6%	-	-	-	-	-
Chironomidae	1246 (432) 13%	1744 (1726) 19%	997 (1142) 25%	249 (432) 10%	1246 (1142) 33%	997 (863) 16%	498 (432) 11%	747 (0) 20%	249 (432) 6%	997 (1142) 10%
Chaoboridae	-	-	-	249 (432) 10%	249 (432) 7%	-	-	-	-	249 (432) 2%
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Trichoptera	2%	-	-	-	-	-	-	-	-	-
miscellaneous	-	-	-	-	-	-	-	7%	-	-

Table 3-33. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the MNS Sites (n=3)

Taxon	MNS 1	MNS 2	MNS 3	MNS 4	MNS 5
Tubificidae	27072 (2355) 88%	50656 (2920) 89%	25245 (10240) 79%	13287 (6602) 65%	9218 (3915) 59%
Naididae	664 (288) 2%	2491 (659) 4%	3322 (2972) 10%	830 (144) 4%	830 (575) 5%
Polychaeta	-	Less 1%	1%	1993 (249) 10%	249 (432) 2%
Nematoda	Less 1%	Less 1%	1744 (249) 5%	1661 (144) 8%	581 (144) 4%
Turbellaria	913 (144) 3%	1%	1%	1%	498 (659) 3%
Bivalvia	1744 (498) 6%	2907 (761) 5%	1163 (381) 4%	1910 (575) 9%	2823 (943) 18%
Gastropoda	1%	Less 1%	Less 1%	-	2%
Hydrachnida	-	-	-	1%	2%
Chironomidae	-	83 (144) Less 1%	83 (144) Less 1%	83 (144) Less 1%	166 (288) 1%
Chaoboridae	-	-	-	-	-
Ephemeroptera	-	-	-	-	-
Trichoptera	-	-	-	1%	415 (144) 3%
miscellaneous	-	-	-	Less 1%	2%

Table 3-34. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the STP Sites (n=3)

Taxon	STP 1	STP 2	STP 3	STP 4	STP 5	STP 6	STP 7	STP 8	STP 10	STP 12
Tubificidae	3737 (2616) 56%	8470 (2755) 54%	1204 (730) 21%	1370 (718) 58%	498 (432) 36%	1744 (1312) 61%	1495 (989) 44%	374 (0) 60%	830 (144) 41%	3571 (1935) 49%
Naididae	997 (1415) 15%	1121 (374) 7%	2408 (2800) 41%	125 (216) 5%	-	-	-	-	83 (144) 4%	332 (381) 5%
Polychaeta	374 (374) 6%	1993 (216) 13%	-	125 (216) 5%	-	374 (374) 13%	374 (374) 11%	-	-	249 (0) 3%
Nematoda	4%	2%	-	-	125 (216) 9%	-	-	-	-	-
Turbellaria	4%	-	1080 (1123) 19%	-	125 (216) 9%	-	-	-	4%	-
Bivalvia	374 (647) 6%	498 (571) 3%	332 (381) 6%	374 (0) 16%	125 (216) 9%	-	249 (216) 7%	-	166 (144) 8%	2076 (1254) 28%
Gastropoda	-	1%	1%	125 (216) 5%	125 (216) 9%	-	-	-	4%	-
Hydrachnida	2%	-	1%	125 (216) 5%	-	4%	4%	-	4%	-
Chironomidae	498 (432) 7%	3114 (940) 20%	540 (190) 9%	125 (216) 5%	249 (432) 18%	623 (778) 22%	1121 (374) 33%	249 (216) 40%	581 (144) 29%	997 (898) 14%
Chaoboridae	2%	-	-	-	-	-	-	-	4%	-
Ephemeroptera	-	1%	-	-	125 (216) 9%	-	-	-	-	-
Trichoptera	-	-	-	-	-	-	-	-	-	-
miscellaneous	-	-	1%	-	-	-	-	-	-	-

Table 3-35. Mean Densities (number/m^2), with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the SUS Sites (n=3 for SUS 1-7; n=1 for SUS 8)

Taxon	SUS 1	SUS 2	SUS 3	SUS 4	SUS 5	SUS 6	SUS 7	SUS 8
Tubificidae	21549 (4819) 79%	30892 (13161) 67%	15820 (3668) 62%	38490 (5505) 85%	10463 (6921) 72%	-	623 (778) 11%	747 10%
Naididae	3114 (2830) 11%	8595 (5389) 19%	2118 (1201) 8%	1370 (432) 3%	747 (374) 5%	1246 (1201) 59%	1495 (1295) 27%	3737 48%
Polychaeta	-	-	1%	-	2%	-	2%	-
Nematoda	Less 1%	1%	1121 (374) 4%	2%	374 (374) 3%	-	-	-
Turbellaria	1%	1%	1%	1619 (1201) 4%	747 (647) 5%	-	-	-
Bivalvia	1495 (747) 5%	3737 (1629) 8%	3986 (1142) 16%	1619 (778) 4%	1%	-	125 (216) 2%	374 5%
Gastropoda	-	Less 1%	1%	1%	-	6%	-	-
Hydrachnida	Less 1%	1%	-	-	1%	-	-	5%
Chironomidae	498 (571) 2%	1495 (747) 3%	1619 (1312) 6%	872 (778) 2%	1370 (532) 9%	623 (432) 29%	2990 (747) 53%	2616 33%
Other Diptera	-	-	-	-	-	-	249 (216) 4%	-
Trichoptera	-	-	-	Less 1%	249 (432) 2%	125 (216) 6%	-	-

Table 3-36. Mean Densities (number/m^2) with Sample Standard Deviations in Parentheses, and Percent Composition of each Macroinvertebrate Group for the WLS Sites (n=3)

Taxon	WLS 1	WLS 2	WLS 3	WLS 4	WLS 5	WLS 6	WLS 7	WLS 8	WLS 9	WLS 10
Tubificidae	1246 (863) 42%	872 (571) 78%	3107 (2488) 59%	4360 (1881) 59%	5232 (374) 65%	16442 (12028) 71%	12083 (5046) 55%	11584 (989) 48%	24290 (12028) 71%	6477 (571) 38%
Naididae	249 (432) 8%	-	374 (374) 4%	125 (216) 2%	-	125 (216) 1%	-	1246 (571) 5%	374 (647) 1%	249 (432) 1%
Polychaeta	498 (432) 17%	-	1246 (1556) 14%	774 (774) 10%	872 (216) 11%	997 (571) 4%	2865 (2625) 13%	5854 (2544) 24%	623 (216) 2%	7847 (2966) 46%
Nematoda	-	-	3%	2%	2%	-	1%	3%	Less 1%	-
Turbellaria	-	-	-	-	-	1%	-	-	-	-
Bivalvia	747 (747) 25%	125 (216) 11%	1370 (778) 16%	1495 (374) 20%	1370 (778) 17%	3363 (1121) 14%	5730 (571) 26%	3488 (2058) 15%	6602 (1415) 19%	1619 (432) 9%
Gastropoda	-	-	-	-	-	-	1%	-	-	-
Hydrachnida	-	-	-	-	3%	-	-	-	-	-
Chironomidae	-	125 (216) 11%	291 (259) 3%	498 (571) 7%	125 (216) 2%	1246 (1079) 5%	623 (571) 3%	997 (216) 4%	1619 (216) 5%	872 (432) 5%
Chaoboridae	-	-	-	-	-	997 (778) 4%	374 (374) 2%	1%	2%	1%
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Trichoptera	249 (432) 8%	-	-	-	125 (216) 2%	-	-	1%	-	-
miscellaneous	-	-	-	-	-	-	-	-	-	-

Table 3-36. Continued

Taxon	WLS 11	WLS 12	WLS 13	WLS 14	WLS 15	WLS 16	WLS 17	WLS 18	WLS 19
Tubificidae	14325 (7770) 67%	23667 (8703) 70%	29522 (17777) 77%	5730 (3668) 39%	4484 (2616) 29%	17813 (4520) 71%	14699 (4850) 41%	3239 (1312) 28%	5730 (1201) 39%
Naididae	747 (0) 4%	9218 (6646) 27%	5605 (0) 15%	872 (571) 6%	125 (216) 1%	4609 (3925) 18%	1744 (1515) 5%	-	-
Polychaeta	-	249 (432) 1%	1121 (1347) 3%	6104 (1726) 41%	8719 (7788) 57%	997 (1079) 4%	17522 (13831) 49%	6104 (2158) 53%	4609 (2830) 31%
Nematoda	1%	-	-	2%	2%	Less 1%	Less 1%	1121 (747) 10%	1121 (747) 8%
Turbellaria	-	-	-	1%	-	-	-	-	-
Bivalvia	3861 (2544) 18%	-	747 (747) 2%	747 (374) 5%	747 (989) 5%	498 (863) 2%	581 (519) 2%	623 (571) 5%	2242 (0) 15%
Gastropoda	-	-	-	1%	2%	-	Less 1%	2%	-
Hydrachnida	-	-	-	-	-	-	-	-	-
Chironomidae	374 (374) 1%	872 (432) 3%	1121 (374) 3%	747 (747) 5%	747 (374) 5%	997 (940) 4%	913 (381) 3%	125 (216) 1%	872 (571) 6%
Chaoboridae	1868 (374) 9%	-	-	1%	-	-	-	-	-
Ephemeroptera	-	-	-	-	-	-	Less 1%	-	-
Trichoptera	-	-	-	-	-	-	Less 1%	-	-
miscellaneous	-	-	-	-	-	-	-	-	-

Table 3-37. Number of Chironomid Larvae with Menta Deformities

Site	Genus	# Larvae with Deformities
DMIR 4	*Procladius*	1 of 21 larvae (4.8%)
SUS 2	*Procladius*	1 of 12 larvae (8.3%)
WLS 4	*Procladius*	1 of 4 larvae (25%)
WLS 7	*Chironomus*	1 of 2 larvae (50%)
WLS 13	*Procladius*	1 of 6 larvae (16.7%)
WLS 19	*Procladius*	1 of 6 larvae (16.7%)

Table 4-1. Triad Analysis Endpoints for Sediment Quality in the Duluth/Superior Harbor

TRIAD ELEMENT	RANKING APPROACH
Sediment Chemistry	Based on magnitude of exceedances of OMOEE guideline values and SEM/AVS ratio exceedances of 1.0
Sediment Toxicity Tests	Based on measured response for each endpoint: • *H. azteca* survival • *C. tentans* survival
Benthic Community Structure	Based on results of each community metric: • Abundance • Taxa richness • Percent oligochaetes • Percent chironomids • Percent taxa which are chironomids

Table 4-2. Number of Surficial Sites Sampled for each Component of the Sediment Quality Triad

	Triad Component		
Site Code	Sediment Chemistry	Sediment Toxicity	Benthos Survey
DMIR	4	4	4
ERP	5	3	4
KMB	5	2	5
HOB	15	8	15
MLH	10	6	10
MNS	5	2	5
STP	10	5	10
SUS	7	4	8
WLS	19	10	19
Total	80	44	80

APPENDIX A

SEDIMENT CHEMISTRY DATA

APPENDIX A

CHEMICAL AND PHYSICAL DATA FILES

The below files are provided on the computer disk at the back of this report. All files are in Microsoft Excel version 5.0. Since all of the files are compressed, access the Readme.txt file first for directions on how to read the files.

File Name	Description
94pahtoc.xls	PAH results (by GC/MS) normalized by TOC
m94pcbco.xls	Selected PCB congener results normalized by TOC
mp94aspb.xls	Total arsenic and lead results for Howard's Bay samples
mp94avs.xls	AVS results
mp94hg.xls	Mercury results
mp94nh3.xls	Ammonia results
mp94pahg.xls	PAH results (by GC/MS)
mp94pahs.xls	Screening PAH results
mp94pcbs.xls	Total PCB results
mp94ps.xls	Particle size results
mp94sem2.xls	SEM results
mp94toc.xls	TOC results
sem_pb.xls	Comparison of SEM lead and total lead results for Howard's Bay
semavsra.xls	SEM/AVS results for selected sites
sumtcdd.xls	TCDD/F results
test_sem.xls	SEM/AVS results for selected sites

APPENDIX B

SEDIMENT TOXICITY TEST REPORTS

FOR *HYALELLA AZTECA* AND *CHIRONOMUS TENTANS*

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 1

Conducted by

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April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of seven of these sediment samples.

SAMPLE COLLECTION AND HANDLING

During August 22-24, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the seven sediments referred to in this report. The composited samples were collected from the harbor using a gravity corer. The samples were stored at 4°C at the Duluth MPCA office until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Seven sediment samples and a control sediment were subjected to 10-day sediment toxicity tests using the procedures described in U.S. EPA (1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable, mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing in Superior, WI. On the test set up day, MPCA personnel picked up the organisms from the supplier and transported them to the MPCA Toxicology Laboratory.

On September 13, 1994, seven samples (DMIR 03, DMIR 04, MLH 01, MLH 02, MLH 03, MLH 04, and MLH 05) and the control sediment were separately homogenized by hand, and 100 mL of each sediment was placed in a test beaker (Batch #1). Each sediment test was set up with four replicates of *H. azteca* and four replicates of *C. tentans*. Approximately 100 mL of aerated, artesian well water was added to the beakers, and the sediments were allowed to settle for approximately two hours before the organisms were added. For each sediment, ten organisms were placed in each of eight beakers in a random fashion.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on September 23, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 110°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. The resulting survival data were analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H. azteca* used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Due to a shortage of test organisms, only two replicates of five organisms each were set up per concentration instead of three replicates.

RESULTS

Water Quality

Measurements of pH, dissolved oxygen concentration, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.8 to 9.0 (Table 1). The water in the *C. tentans* beakers had a pH range of 7.6 to 8.4 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 4.5 to 6.5 mg/L in the *H. azteca* beakers and from 2.4 to 6.5 mg/L in the *C. tentans* beakers (Table 2). All dissolved oxygen concentrations were within acceptable limits (i.e., greater than 40% saturated).

The temperature of the overlying water in each glass box was measured and ranged from 22.0°C to 24.0°C for both tests (Table 3). The recommended temperature range for these tests is 23 ± 1°C (U.S. EPA, 1994).

Test Endpoints

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 88% with a range of 80% to 100%. For the control sediment containing *C. tentans,* percent survival ranged from 70% to 100% with a mean of 82%. Survival for these controls was acceptable, and both tests passed.

Mean percent survival of *H. azteca* in the test sediments ranged from 65% in the MLH 04 sediment to 98% in the DMIR 04 sediment. Mean percent survival of *C. tentans* in the test sediments ranged from 70% in the MLH 02 and MLH 03 samples to 82% in the MLH 05 sample.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

Data Analysis

Most of the survival data were transformed using an arc sine-square root transformation before being analyzed statistically using Dunnett's test. A one-tailed test was used to test the alternative hypothesis that sample survival was less than control survival. Thus, it was not necessary to include the *H. azteca* mean percent survival data for DMIR 04 (98%) and MLH 03 (90%) which exceeded the control survival of 88%.

Only the survival of *H. azteca* in the MLH 04 sediment was significantly less than the control. The survival of organisms in all other sediments was not significantly less than the respective controls as determined by 1-tailed Dunnett's tests at p=0.05. Results of the statistical analyses of these data are included in Appendix A.

Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution

The pH of the overlying water in the reference toxicant test ranged from 8.0 to 8.6. The dissolved oxygen ranged from 7.4 to 7.9 mg/L, and the temperature of the overlying water ranged from 22.0°C to 24.0°C. Survival of the organisms in the control was less than 90% (i.e., 80%) which was unacceptable. Thus, the health of the *H. azteca* used in the test was suspect, and the test failed. The test was also suspect due to an inadequate number of replicates (i.e., two replicates instead of three) used in the test.

SUMMARY

Survival of *H. azteca* in the control sediments was acceptable (i.e., greater than 80%), and sample MLH 04 caused significant toxicity to *H. azteca* (p=0.05). Although the reference toxicant test failed, the health of the culture appeared to be acceptable for use in the toxicity test.

Control survival was acceptable in the *C. tentans* test (i.e., greater than 70%), and none of the test sediments resulted in significantly lower survival of *C. tentans* when compared to the control survival (p = 0.05).

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

	Control 1		DMIR 03		DMIR 04		MLH 01	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	7.6	7.8	7.8	8.0	8.0	8.0	8.3	9.0
1	7.7	8.0	7.8	7.9	7.9	8.0	8.0	8.2
2	7.6	7.9	7.8	7.8	7.9	8.0	7.9	8.2
3	7.8	8.0	7.8	7.9	7.9	7.9	8.1	8.2
4	8.0	8.1	8.0	8.2	8.1	8.1	8.1	8.1
5	7.8	7.9	7.9	8.0	8.0	8.0	8.2	8.5
6	7.8	7.9	7.9	8.0	8.0	7.9	8.1	8.3
7	7.7	8.0	7.7	7.9	8.0	8.0	8.1	8.2
8	7.8	8.0	7.8	8.1	7.9	8.1	8.1	8.3
9	7.7	8.0	7.7	8.0	8.0	8.1	7.8	8.0
Range	7.6-8.0	7.8-8.1	7.7-8.0	7.8-8.2	7.9-8.1	7.9-8.1	7.8-8.3	8.0-9.0

	MLH 02		MLH 03		MLH 04		MLH 05	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	8.4	8.3	8.0	8.2	8.0	7.9	8.0	8.0
1	8.1	8.1	8.0	8.0	8.0	8.1	7.9	8.0
2	8.1	8.1	7.9	8.0	8.0	8.0	7.9	8.0
3	8.1	8.2	8.0	8.0	8.0	8.0	8.0	8.0
4	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8.1
5	8.1	8.2	8.0	8.1	8.0	8.0	8.0	8.0
6	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0
7	8.2	8.2	8.0	8.2	8.1	8.1	8.0	8.1
8	8.1	8.2	8.0	8.1	8.0	8.1	8.0	8.1
9	8.1	8.1	8.0	8.1	8.0	8.1	8.0	8.1
Range	8.1-8.4	8.1-8.3	7.9-8.2	8.0-8.2	8.0-8.1	7.9-8.1	7.9-8.1	8.0-8.1

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

	Control 1		DMIR 03		DMIR 04		MLH 01	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	5.5	5.5	5.2	6.5	4.8	5.9	5.0	5.6
1	4.5	5.6	4.7	5.7	4.5	5.5	5.0	5.5
2	4.4	5.3	3.8	5.5	3.3	4.5	4.5	5.7
3	5.1	5.5	4.3	5.6	4.4	4.6	4.6	5.8
4	5.0	6.1	4.8	5.6	4.6	5.8	5.3	6.1
5	4.3	5.9	4.9	5.5	3.7	5.1	4.7	6.0
6	3.0	6.0	4.1	5.5	4.2	5.6	4.7	6.3
7	3.7	5.9	2.7	5.6	5.5	5.3	4.5	5.9
8	4.5	6.1	3.2	5.7	4.1	5.4	4.3	6.1
9	3.9	5.9	2.4	5.8	3.7	5.8	3.9	6.3
Range	3.0-5.5	5.3-6.1	2.4-5.2	5.5-6.5	3.3-5.5	4.5-5.9	3.9-5.3	5.5-6.3

	MLH 02		MLH 03		MLH 04		MLH 05	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	6.5	6.1	5.4	5.5	5.8	6.0	5.5	6.0
1	5.0	5.8	4.9	5.9	4.8	5.9	4.8	5.9
2	4.6	5.7	4.9	5.5	4.1	5.8	4.1	5.7
3	4.1	5.4	5.1	5.5	5.2	5.7	5.0	5.5
4	5.2	6.2	5.2	6.0	5.4	6.0	5.0	5.9
5	5.1	6.1	5.3	5.7	5.2	5.8	5.7	5.9
6	4.9	6.2	5.0	6.2	4.9	6.0	4.0	6.0
7	5.4	6.1	4.7	5.8	5.9	6.0	5.0	6.3
8	5.2	6.1	4.5	6.1	5.3	6.4	4.1	6.4
9	4.2	6.4	4.4	6.3	5.0	6.5	3.5	6.3
Range	4.1-6.5	5.4-6.4	4.4-5.4	5.5-6.3	4.1-5.9	5.7-6.5	3.5-5.7	5.5-6.4

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control 1		DMIR 03		DMIR 04		MLH 01	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	23.0	23.0	23.0	23.0	23.0	23.0	24.0	24.0
1	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
2	23.5	23.5	24.0	24.0	23.5	23.5	24.0	24.0
3	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5
4	23.0	23.0	23.5	23.5	23.0	23.0	23.5	23.5
5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
6	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
7	23.0	23.0	23.0	23.0	23.0	23.0	23.5	23.5
8	23.0	23.0	23.5	23.5	23.5	23.5	23.5	23.5
9	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0
Range	22.5-24.0	22.5-24.0	22.5-24.0	22.5-24.0	22.5-24.0	22.5-24.0	22.5-24.0	22.5-24.0

	MLH 02		MLH 03		MLH 04		MLH 05	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
1	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5
2	23.5	23.5	23.5	23.5	23.5	23.5	23.5	23.5
3	23.0	23.0	23.5	23.5	23.5	23.5	23.0	23.0
4	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
5	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
6	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
7	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
8	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
9	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Range	22.0-23.5	22.0-23.5	22.0-23.5	22.0-23.5	22.0-23.5	22.0-23.5	22.0-23.5	22.0-23.5

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

Batch #1	Mean Percent Survival	
	Hyalella azteca	*Chironomus tentans*
CONTROL #1	88%	82%
DMIR 03	82%	72%
DMIR 04	98%	75%
MLH 01	75%	75%
MLH 02	80%	70%
MLH 03	90%	70%
MLH 04	65%*	72%
MLH 05	82%	82%

* Significantly less survival than the control, p = 0.05.

APPENDIX A

Statistical Analyses

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
6 sediments (4 replicates per sediment)

control
0.90000000
0.80000000
1.00000000
0.80000000

mlh 1
0.90000000
0.80000000
0.60000000
0.70000000

mlh 2
0.90000000
0.70000000
0.70000000
0.90000000

mlh 4
0.80000000
0.60000000
0.50000000
0.70000000

mlh 5
0.80000000
0.90000000
0.70000000
0.90000000

dmir 3
0.80000000
0.90000000
0.80000000
0.80000000

TITLE: 94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
FILE: 94MUD1.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	control	1	0.9000	1.2490
1	control	2	0.8000	1.1071
1	control	3	1.0000	1.4120
1	control	4	0.8000	1.1071
2	mlh 1	1	0.9000	1.2490
2	mlh 1	2	0.8000	1.1071
2	mlh 1	3	0.6000	0.8861
2	mlh 1	4	0.7000	0.9912
3	mlh 2	1	0.9000	1.2490
3	mlh 2	2	0.7000	0.9912
3	mlh 2	3	0.7000	0.9912
3	mlh 2	4	0.9000	1.2490
4	mlh 4	1	0.8000	1.1071
4	mlh 4	2	0.6000	0.8861
4	mlh 4	3	0.5000	0.7854
4	mlh 4	4	0.7000	0.9912
5	mlh 5	1	0.8000	1.1071
5	mlh 5	2	0.9000	1.2490
5	mlh 5	3	0.7000	0.9912
5	mlh 5	4	0.9000	1.2490
6	dmir 3	1	0.8000	1.1071
6	dmir 3	2	0.9000	1.2490
6	dmir 3	3	0.8000	1.1071
6	dmir 3	4	0.8000	1.1071

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	control	4	1.107	1.412	1.219
2	mlh 1	4	0.886	1.249	1.058
3	mlh 2	4	0.991	1.249	1.120
4	mlh 4	4	0.785	1.107	0.942
5	mlh 5	4	0.991	1.249	1.149
6	dmir 3	4	1.107	1.249	1.143

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	control	0.021	0.145	0.073	11.91
2	mlh 1	0.024	0.156	0.078	14.73
3	mlh 2	0.022	0.149	0.074	13.29
4	mlh 4	0.019	0.138	0.069	14.67
5	mlh 5	0.016	0.125	0.062	10.86
6	dmir 3	0.005	0.071	0.035	6.21

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Shapiro - Wilk's test for normality

D = 0.322

W = 0.931

Critical W (P = 0.05) (n = 24) = 0.916
Critical W (P = 0.01) (n = 24) = 0.884

Data **PASS normality test at P=0.01 level**. Continue analysis.

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 1.73

Table Chi-square value = 15.09 (alpha = 0.01, df = 5)
Table Chi-square value = 11.07 (alpha = 0.05, df = 5)

Data **PASS B1 homogeneity test at 0.01 level**. Continue analysis.

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.181	0.036	2.021
Within (Error)	18	0.322	0.018	
Total	23	0.502		

Critical F value = 2.77 (0.05,5,18)
Since F < Critical F FAIL TO REJECT Ho: All equal

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	control	1.219	0.875		
2	mlh 1	1.058	0.750	1.698	
3	mlh 2	1.120	0.800	1.044	
4	**mlh 4**	0.942	0.650	2.924	*
5	mlh 5	1.149	0.825	0.738	
6	dmir 3	1.143	0.825	0.806	

Dunnett table value = 2.41 (1 Tailed Value, P=0.05, df=18,5)

94 MUDPUPPY RUN #1 *Hyalella azteca* 9/13/94
File: 94MUD1.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	control	4			
2	mlh 1	4	0.181	20.7	0.125
3	mlh 2	4	0.181	20.7	0.075
4	mlh 4	4	0.181	20.7	0.225
5	mlh 5	4	0.181	20.7	0.050
6	dmir 3	4	0.181	20.7	0.050

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
8 sediments (4 replicates per sediment)
control
1.00000000
0.80000000
0.80000000
0.70000000
mlh 1
0.70000000
0.80000000
0.80000000
0.70000000
mlh 2
0.70000000
0.50000000
0.70000000
0.90000000
mlh 4
0.70000000
0.80000000
0.70000000
0.70000000
mlh 5
1.00000000
0.90000000
0.60000000
0.80000000
dmir 3
0.50000000
0.80000000
0.80000000
0.80000000
dmir 4
0.80000000
1.00000000
0.50000000
0.70000000
mlh 3
0.7
0.7
0.7
0.7

TITLE: 94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
FILE: 94MUD1ch.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 8

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	control	1	1.0000	1.4120
1	control	2	0.8000	1.1071
1	control	3	0.8000	1.1071
1	control	4	0.7000	0.9912
2	mlh 1	1	0.7000	0.9912
2	mlh 1	2	0.8000	1.1071
2	mlh 1	3	0.8000	1.1071
2	mlh 1	4	0.7000	0.9912
3	mlh 2	1	0.7000	0.9912
3	mlh 2	2	0.5000	0.7854
3	mlh 2	3	0.7000	0.9912
3	mlh 2	4	0.9000	1.2490
4	mlh 4	1	0.7000	0.9912
4	mlh 4	2	0.8000	1.1071
4	mlh 4	3	0.7000	0.9912
4	mlh 4	4	0.7000	0.9912
5	mlh 5	1	1.0000	1.4120
5	mlh 5	2	0.9000	1.2490
5	mlh 5	3	0.6000	0.8861
5	mlh 5	4	0.8000	1.1071
6	dmir 3	1	0.5000	0.7854
6	dmir 3	2	0.8000	1.1071
6	dmir 3	3	0.8000	1.1071
6	dmir 3	4	0.8000	1.1071
7	dmir 4	1	0.8000	1.1071
7	dmir 4	2	1.0000	1.4120
7	dmir 4	3	0.5000	0.7854
7	dmir 4	4	0.7000	0.9912
8	mlh 3	1	0.7000	0.9912
8	mlh 3	2	0.7000	0.9912
8	mlh 3	3	0.7000	0.9912
8	mlh 3	4	0.7000	0.9912

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
File: 94MUD1ch.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	control	4	0.991	1.412	1.154
2	mlh 1	4	0.991	1.107	1.049
3	mlh 2	4	0.785	1.249	1.004
4	mlh 4	4	0.991	1.107	1.020
5	mlh 5	4	0.886	1.412	1.164
6	dmir 3	4	0.785	1.107	1.027
7	dmir 4	4	0.785	1.412	1.074
8	mlh 3	4	0.991	0.991	0.991

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
File: 94MUD1ch.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	control	0.032	0.180	0.090	15.62
2	mlh 1	0.004	0.067	0.033	6.38
3	mlh 2	0.036	0.190	0.095	18.91
4	mlh 4	0.003	0.058	0.029	5.69
5	mlh 5	0.050	0.223	0.112	19.17
6	dmir 3	0.026	0.161	0.080	15.67
7	dmir 4	0.069	0.262	0.131	24.37
8	mlh 3	0.000	0.000	0.000	0.00

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
File: 94MUD1ch.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Shapiro - Wilk's test for normality

D = 0.662

W = 0.942

Critical W (P = 0.05) (n = 32) = 0.930
Critical W (P = 0.01) (n = 32) = 0.904

Data **PASS normality test at P=0.01 level**. Continue analysis.

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
File: 94MUD1ch.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance

These two tests can not be performed because at least one group has zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

---

94 MUDPUPPY RUN #1 CHIRONOMIDS 9/13/94
File: 94MUD1ch.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	control	1.154				
2	mlh 1	1.049	15.00	None	4.00	
3	mlh 2	1.004	14.00	None	4.00	
4	mlh 4	1.020	13.50	None	4.00	
5	mlh 5	1.164	18.50	None	4.00	
6	dmir 3	1.027	16.00	None	4.00	
7	dmir 4	1.074	16.00	None	4.00	
8	mlh 3	0.991	12.00	None	4.00	

Critical values use k = 7, are 1 tailed, and alpha = 0.05

WARNING - There are no critical values for this combination of groups and replicates.

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 2

Conducted by

Minnesota Pollution Control Agency
Monitoring and Assessment Section
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April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of eleven of these sediment samples.

SAMPLE COLLECTION AND HANDLING

During August 23-24, 1994 and September 21-23, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the eleven sediments referred to in this report. The samples were collected from the harbor using a gravity corer. The samples were stored at 4°C until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Eleven sediment samples and a control sediment were subjected to the 10-day sediment toxicity test using standard methods for this analysis (U.S. EPA, 1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a mini-flow system (Benoit et al., 1993; U.S. EPA, 1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing, Superior, WI prior to the test set up.

On October 4, 1994, eleven samples (DMIR 01, DMIR 02, MLH 06, SUS 01, SUS 03, WLS 01, WLS 02, WLS 03, WLS 04, WLS 06, and WLS 08) and the control sediment were separately homogenized by hand, and 100 mL of each sediment were placed in a test beaker. Each sediment test was set up with four replicates of *H. azteca* and four replicates of *C. tentans*. Approximately 100 mL of aerated artesian well water was added to the beakers, and the sediments were allowed to settle for approximately two hours before the organisms were added. For each sediment, ten organisms were placed in each of eight beakers in a random fashion.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on October 14, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 100°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. The survival data were analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H. azteca* used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Three replicates of five organisms each were set up per concentration.

RESULTS

Water Quality

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.1 to 8.1 (Table 1). The water in the *C. tentans* beakers had a pH range of 6.9 to 8.0 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 3.7 to 6.4 mg/L in the *H. azteca* beakers and from 1.7 to 6.1 mg/L in the *C. tentans* beakers (Table 2). All dissolved oxygen concentrations were within acceptable limits (i.e., greater than 40% saturated).

The temperature of the overlying water in each glass box was measured and ranged from 21.5°C to 23.0°C for both tests (Table 3). The recommended temperature range for these tests is 23 ± 1°C (U.S. EPA, 1994).

Test Endpoints

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 92% with a range of 90% to 100%. For the control sediment containing *C. tentans,* percent survival ranged from 80% to 100% with a mean of 95%. Survival for these controls was acceptable, and both tests passed.

Mean percent survival of *H. azteca* in the test sediments ranged from 70% in the DMIR 01 sediment to 98% in the WLS 04 sediment. Mean percent survival of *C. tentans* in the test sediments ranged from 55% in the SUS 03 sample to 92% in the MLH 06 sample.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

Data Analysis

Most of the survival data were transformed using an arc sine-square root transformation before being subjected to statistical analysis. A one-tailed test was used to test the alternative hypothesis that sample survival was less than control survival. Thus, it was not necessary to include the *H. azteca* mean percent survival data for DMIR 02 (95%) and WLS 04 (98%) which exceeded the control survival of 92%. When TOXSTAT was run on the rest of the *H. azteca* samples, the data were non-normal due to the survival of the WLS 03 replicates (i.e., 90%, 20%, 90%, and 90%). This resulted in Steel's Many-one Rank test being run on the data set. None of the sample survivals were significantly less than the control survival ($\propto = 0.05$). However, because the replicate survival for WLS 03 was consistently high (i.e., 90%) except for one replicate (i.e., 20%), this sample was removed from the data set so that a stronger, parametric statistical analysis could be conducted. When Dunnett's test was used, DMIR 01 had significantly less *H. azteca* survival than the corresponding control ($p = 0.05$).

For *C.* tentans, Dunnett's test was used to determine that DMIR 01, SUS 03, and WLS 01 had significantly lower survival than the control ($p = 0.05$). Results of the statistical analyses of these data are included in Appendix A.

Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution

The pH of the overlying water in the reference toxicant test ranged from 7.8 to 8.5. The dissolved oxygen ranged from 6.4 to 8.3 mg/L, and the temperature of the overlying water ranged from 21.0°C to 22.5°C. Survival of the organisms in the control was less than 90% (i.e., 53%) which was unacceptable. Although two of the control replicates had 100% survival at the end of the test, the third replicate experienced complete mortality of the *Hyalella*. The reason for this complete mortality could not be determined. Thus, the test failed.

SUMMARY

Although the survival of *H. azteca* in the control sediment was acceptable (i.e., greater than 80%), the corresponding reference toxicant test failed due to poor control survival in one of the replicates. The reason for this reference toxicant failure could not be determined. From the *H. azteca* data that were analyzed statistically, only DMIR 01 had significantly less survival than the corresponding control survival ($p = 0.05$).

Control survival was acceptable in the *C. tentans* test (i.e., greater than 70%), and only the survival of organisms in the DMIR 01, SUS 03, and WLS 01 sediments was significantly less than that of the control as determined by a 1-tailed Dunnett's test ($p=0.05$).

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

Day	Control #2 *C. tentans*	Control #2 *H. azteca*	DMIR 01 *C. tentans*	DMIR 01 *H. azteca*	DMIR 02 *C. tentans*	DMIR 02 *H. azteca*	MLH 06 *C. tentans*	MLH 06 *H. azteca*	SUS 01 *C. tentans*	SUS 01 *H. azteca*	SUS 03 *C. tentans*	SUS 03 *H. azteca*
0	7.9	7.8	7.8	8.0	8.0	7.8	7.9	8.0	7.8	7.6	6.9	7.1
1	7.7	7.7	8.0	8.1	7.9	7.8	7.9	8.0	7.5	7.5	7.8	7.7
2	7.7	7.7	7.8	7.9	7.8	7.7	7.8	7.9	7.7	7.7	7.9	7.8
3	7.7	7.7	7.8	7.9	7.9	7.9	7.8	7.9	7.8	7.8	7.8	7.8
4	7.8	7.8	7.9	8.0	7.9	7.9	7.9	8.0	7.8	7.8	8.0	7.9
5 *												
6	7.8	7.8	7.9	8.0	8.0	7.9	7.9	8.0	7.9	7.8	7.9	7.9
7	7.7	7.7	8.0	8.0	8.0	7.9	8.0	8.0	8.0	7.8	8.0	7.9
8	7.8	7.8	7.9	7.9	7.9	7.9	7.9	7.9	7.5	7.6	7.8	7.8
9	7.7	7.7	7.9	7.9	7.8	7.9	7.9	7.9	7.9	7.8	7.8	7.8
Range	7.7-7.9	7.7-7.8	7.8-8.0	7.9-8.1	7.8-8.0	7.7-7.9	7.8-8.0	7.9-8.0	7.5-8.0	7.5-7.8	6.9-8.0	7.1-7.9

* No measurements taken on this day.

Day	WLS 01 *C. tentans*	WLS 01 *H. azteca*	WLS 02 *C. tentans*	WLS 02 *H. azteca*	WLS 03 *C. tentans*	WLS 03 *H. azteca*	WLS 04 *C. tentans*	WLS 04 *H. azteca*	WLS 06 *C. tentans*	WLS 06 *H. azteca*	WLS 08 *C. tentans*	WLS 08 *H. azteca*
0	7.7	7.7	7.8	7.8	7.6	7.6	7.3	7.4	7.6	7.7	7.7	7.6
1	7.7	7.6	8.0	7.9	7.6	7.7	7.7	7.7	7.8	7.7	7.7	7.6
2	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.8	7.7
3	7.2	7.7	7.8	7.8	8.0	8.0	7.8	7.8	7.9	7.8	7.8	7.8
4	7.8	7.8	7.8	7.8	7.8	7.9	7.8	7.8	7.9	7.8	7.8	7.8
5 *												
6	7.9	7.8	7.9	7.9	7.9	7.9	8.0	7.8	7.9	7.9	8.0	7.9
7	7.8	7.8	7.9	7.9	7.9	7.7	7.8	7.8	7.9	7.8	7.9	7.8
8	7.8	7.7	7.9	7.8	7.8	7.7	7.8	7.7	7.6	7.7	7.8	7.7
9	7.7	7.8	7.7	7.8	7.9	7.9	7.9	7.8	7.9	7.9	7.8	7.8
Range	7.2-7.9	7.6-7.8	7.7-8.0	7.7-7.9	7.6-8.0	7.6-8.0	7.3-8.0	7.4-7.8	7.6-7.9	7.7-7.9	7.7-8.0	7.6-7.9

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

Day	Control #2 *C. tentans*	Control #2 *H. azteca*	DMIR 01 *C. tentans*	DMIR 01 *H. azteca*	DMIR 02 *C. tentans*	DMIR 02 *H. azteca*	MLH 06 *C. tentans*	MLH 06 *H. azteca*	SUS 01 *C. tentans*	SUS 01 *H. azteca*	SUS 03 *C. tentans*	SUS 03 *H. azteca*
0	5.8	4.9	5.6	5.5	6.1	5.4	4.9	6.3	5.9	5.1	5.1	5.4
1	5.3	5.8	5.8	6.0	5.0	5.5	5.9	6.3	5.1	5.5	5.7	5.5
2	3.5	5.3	3.7	5.4	3.7	3.8	3.4	5.6	4.2	5.2	4.3	5.6
3	2.8	5.5	3.2	5.4	3.6	4.5	3.4	5.5	3.8	5.5	4.2	5.0
4	3.0	5.7	3.6	5.9	1.7	5.3	4.3	6.4	3.3	5.7	3.9	5.1
5 *												
6	4.2	6.0	2.5	5.5	2.7	5.8	4.7	6.4	3.5	5.4	3.8	5.0
7	3.5	6.3	3.9	6.0	3.5	5.8	4.3	6.4	3.4	5.4	4.3	5.4
8	3.0	6.0	4.7	6.2	3.8	5.5	4.3	6.3	3.5	5.4	5.1	5.2
9	3.7	5.4	3.4	5.9	3.1	5.5	4.2	6.1	3.6	5.0	4.1	5.3
Range	2.8-5.8	4.9-6.3	2.5-5.8	5.4-6.2	1.7-6.1	3.8-5.8	3.4-5.9	5.5-6.4	3.3-5.9	5.0-5.7	3.8-5.7	5.0-5.6

* No measurements taken on this day.

Day	WLS 01 *C. tentans*	WLS 01 *H. azteca*	WLS 02 *C. tentans*	WLS 02 *H. azteca*	WLS 03 *C. tentans*	WLS 03 *H. azteca*	WLS 04 *C. tentans*	WLS 04 *H. azteca*	WLS 06 *C. tentans*	WLS 06 *H. azteca*	WLS 08 *C. tentans*	WLS 08 *H. azteca*
0	5.8	5.9	5.9	5.3	5.9	5.5	6.1	6.4	5.4	5.3	5.5	6.1
1	5.2	5.9	5.6	5.3	4.9	6.0	5.0	5.5	5.4	5.3	5.4	6.0
2	4.4	5.7	3.2	5.1	3.9	5.2	3.2	4.7	4.0	5.2	4.2	5.3
3	4.0	5.3	3.7	5.2	3.5	5.4	2.9	3.7	3.2	4.9	3.6	5.1
4	4.4	6.1	4.5	5.4	3.7	6.0	2.0	5.0	4.2	5.6	4.4	6.0
5 *												
6	4.1	5.6	4.6	5.5	3.0	5.8	3.0	4.8	3.8	5.3	4.1	5.6
7	4.2	5.6	4.3	5.2	4.1	6.3	3.8	5.3	4.1	5.9	4.6	5.8
8	3.9	5.2	4.2	5.8	4.4	5.6	3.3	4.9	3.8	5.6	3.9	5.3
9	4.2	5.0	3.8	5.4	4.5	5.2	3.4	5.1	3.3	5.4	4.2	5.6
Range	3.9-5.8	5.0-6.1	3.2-5.9	5.1-5.8	3.0-5.9	5.2-6.3	2.0-6.1	3.7-6.4	3.2-5.4	4.9-5.9	3.6-5.5	5.1-6.1

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control #2		DMIR 01		DMIR 02		MLH 06		SUS 01		SUS 03	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
1	23.0	23.0	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	22.5	22.5
3	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
4	23.0	23.0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
5 *												
6	22.0	22.0	21.5	21.5	22.0	22.0	22.0	22.0	22.0	22.0	21.5	21.5
7	22.5	22.5	22.0	22.0	22.0	22.0	22.0	22.0	22.5	22.5	22.0	22.0
8	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
9	21.5	21.5	22.0	22.0	22.0	22.0	21.5	21.5	22.0	22.0	22.0	22.0
Range	21.5-23.0	21.5-23.0	21.5-23.0	21.5-23.0	22.0-23.0	22.0-23.0	21.5-23.0	21.5-23.0	22.0-23.0	22.0-23.0	21.5-23.0	21.5-23.0

* No measurements taken on this day.

	WLS 01		WLS 02		WLS 03		WLS 04		WLS 06		WLS 08	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	22.0	22.0	22.0	22.0	22.0	22.0	21.5	21.5	22.0	22.0	22.0	22.0
1	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
2	22.5	22.5	23.0	23.0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
3	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
5 *												
6	21.5	21.5	22.0	22.0	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
7	22.0	22.0	22.0	22.0	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
8	21.5	21.5	22.0	22.0	21.5	21.5	21.5	21.5	22.0	22.0	21.5	21.5
9	22.0	22.0	22.0	22.0	21.5	21.5	21.5	21.5	22.0	22.0	21.5	21.5
Range	21.5-22.5	21.5-22.5	22.0-23.0	22.0-23.0	21.5-22.5	21.5-22.5	21.5-22.5	21.5-22.5	21.5-22.5	21.5-22.5	21.5-22.5	21.5-22.5

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

	Mean Percent Survival	
Batch #2	*Hyalella azteca*	*Chironomus tentans*
CONTROL #2	92%	95%
DMIR 01	70%*	72%*
DMIR 02	95%	88%
MLH 06	92%	92%
SUS 01	85%	72%
SUS 03	92%	55%*
WLS 01	85%	68%*
WLS 02	90%	90%
WLS 03	72%	80%
WLS 04	98%	78%
WLS 06	90%	80%
WLS 08	90%	80%

* Significantly less survival than the control, p = 0.05.

APPENDIX A

Statistical Analyses

94 MUDPUPPY RUN #2 *Hyalella azteca* 10/4/94
9 SEDIMENTS (4 replicates per sediment)

CONTROL
0.9
0.9
0.9
1.0

MLH 6
1.0
1.0
0.9
0.8

SUS 1
0.9
0.8
0.9
0.8

SUS 3
0.8
1.0
0.9
1.0

WLS 1
0.7
1.0
0.7
1.0

WLS 2
0.9
1.0
0.8
0.9

WLS 6
0.8
0.9
1.0
0.9

WLS 8
0.8
1.0
1.0
0.8

DMIR 1
0.8
0.6
0.8
0.6

TITLE: 94 MUDPUPPY RUN #2 *Hyalella azteca* 10/4/94
FILE: 94MUD2X.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 9

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.9000	1.2490
1	CONTROL	2	0.9000	1.2490
1	CONTROL	3	0.9000	1.2490
1	CONTROL	4	1.0000	1.4120
2	MLH 6	1	1.0000	1.4120
2	MLH 6	2	1.0000	1.4120
2	MLH 6	3	0.9000	1.2490
2	MLH 6	4	0.8000	1.1071
3	SUS 1	1	0.9000	1.2490
3	SUS 1	2	0.8000	1.1071
3	SUS 1	3	0.9000	1.2490
3	SUS 1	4	0.8000	1.1071
4	SUS 3	1	0.8000	1.1071
4	SUS 3	2	1.0000	1.4120
4	SUS 3	3	0.9000	1.2490
4	SUS 3	4	1.0000	1.4120
5	WLS 1	1	0.7000	0.9912
5	WLS 1	2	1.0000	1.4120
5	WLS 1	3	0.7000	0.9912
5	WLS 1	4	1.0000	1.4120
6	WLS 2	1	0.9000	1.2490
6	WLS 2	2	1.0000	1.4120
6	WLS 2	3	0.8000	1.1071
6	WLS 2	4	0.9000	1.2490
7	WLS 6	1	0.8000	1.1071
7	WLS 6	2	0.9000	1.2490
7	WLS 6	3	1.0000	1.4120
7	WLS 6	4	0.9000	1.2490
8	WLS 8	1	0.8000	1.1071
8	WLS 8	2	1.0000	1.4120
8	WLS 8	3	1.0000	1.4120
8	WLS 8	4	0.8000	1.1071
9	DMIR 1	1	0.8000	1.1071
9	DMIR 1	2	0.6000	0.8861
9	DMIR 1	3	0.8000	1.1071
9	DMIR 1	4	0.6000	0.8861

94 MUDPUPPY RUN #*2C Hyalella azteca* 10/4/94
File: 94MUD2X.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	1.249	1.412	1.290
2	MLH 6	4	1.107	1.412	1.295
3	SUS 1	4	1.107	1.249	1.178
4	SUS 3	4	1.107	1.412	1.295
5	WLS 1	4	0.991	1.412	1.202
6	WLS 2	4	1.107	1.412	1.254
7	WLS 6	4	1.107	1.412	1.254
8	WLS 8	4	1.107	1.412	1.260
9	DMIR 1	4	0.886	1.107	0.997

94 MUDPUPPY RUN #2C *Hyalella azteca* 10/4/94
File: 94MUD2X.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.007	0.081	0.041	6.32
2	MLH 6	0.022	0.147	0.073	11.35
3	SUS 1	0.007	0.082	0.041	6.95
4	SUS 3	0.022	0.147	0.073	11.35
5	WLS 1	0.059	0.243	0.121	20.22
6	WLS 2	0.016	0.125	0.062	9.93
7	WLS 6	0.016	0.125	0.062	9.93
8	WLS 8	0.031	0.176	0.088	13.97
9	DMIR 1	0.016	0.128	0.064	12.81

```
94 MUDPUPPY RUN #2C Hyalella azteca 10/4/94
File: 94MUD2X.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
---------------------------------------------------------------------

D =    0.582

W =    0.926

Critical W (P = 0.05) (n = 36) = 0.935
Critical W (P = 0.01) (n = 36) = 0.912
---------------------------------------------------------------------

Data PASS normality test at P=0.01 level. Continue analysis.


94 MUDPUPPY RUN #2C HYALELLA 10/4/94
File: 94MUD2X.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

---------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    5.08

---------------------------------------------------------------------
Table Chi-square value =   20.09  (alpha = 0.01, df =   8)
Table Chi-square value =   15.51  (alpha = 0.05, df =   8)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

94 MUDPUPPY RUN #2C *Hyalella azteca* 10/4/94
File: 94MUD2X.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	8	0.287	0.036	1.667
Within (Error)	27	0.582	0.022	
Total	35	0.869		

Critical F value = 2.31 (0.05,8,27)
Since F < Critical F FAIL TO REJECT Ho: All equal

94 MUDPUPPY RUN #2 *Hyalella azteca* 10/4/94
File: 94MUD2X.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	1.290	0.925		
2	MLH 6	1.295	0.925	-0.051	
3	SUS 1	1.178	0.850	1.076	
4	SUS 3	1.295	0.925	-0.051	
5	WLS 1	1.202	0.850	0.850	
6	WLS 2	1.254	0.900	0.342	
7	WLS 6	1.254	0.900	0.342	
8	WLS 8	1.260	0.900	0.291	
9	**DMIR 1**	0.997	0.700	2.825	*

Dunnett table value = 2.53 (1 Tailed Value, P=0.05, df=24,8)

94 MUDPUPPY RUN #2 *Hyalella azteca* 10/4/94
File: 94MUD2X.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	4			
2	MLH 6	4	0.191	20.6	0.000
3	SUS 1	4	0.191	20.6	0.075
4	SUS 3	4	0.191	20.6	0.000
5	WLS 1	4	0.191	20.6	0.075
6	WLS 2	4	0.191	20.6	0.025
7	WLS 6	4	0.191	20.6	0.025
8	WLS 8	4	0.191	20.6	0.025
9	DMIR 1	4	0.191	20.6	0.225

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
7 sediments (4 replicates per sediment)

control
0.80000000
1.00000000
1.00000000
1.00000000
MLH 6
1.00000000
0.90000000
1.00000000
0.80000000
SUS 1
0.70000000
0.90000000
0.80000000
0.50000000
SUS 3
0.70000000
0.40000000
0.40000000
0.70000000
WLS 1
0.60000000
0.90000000
0.40000000
0.80000000
WLS 2
0.80000000
1.00000000
0.80000000
1.00000000
WLS 3
0.70000000
0.90000000
0.90000000
0.70000000

TITLE: 94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
FILE: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y))   NUMBER OF GROUPS: 7

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	control	1	0.8000	1.1071
1	control	2	1.0000	1.4120
1	control	3	1.0000	1.4120
1	control	4	1.0000	1.4120
2	MLH 6	1	1.0000	1.4120
2	MLH 6	2	0.9000	1.2490
2	MLH 6	3	1.0000	1.4120
2	MLH 6	4	0.8000	1.1071
3	SUS 1	1	0.7000	0.9912
3	SUS 1	2	0.9000	1.2490
3	SUS 1	3	0.8000	1.1071
3	SUS 1	4	0.5000	0.7854
4	SUS 3	1	0.7000	0.9912
4	SUS 3	2	0.4000	0.6847
4	SUS 3	3	0.4000	0.6847
4	SUS 3	4	0.7000	0.9912
5	WLS 1	1	0.6000	0.8861
5	WLS 1	2	0.9000	1.2490
5	WLS 1	3	0.4000	0.6847
5	WLS 1	4	0.8000	1.1071
6	WLS 2	1	0.8000	1.1071
6	WLS 2	2	1.0000	1.4120
6	WLS 2	3	0.8000	1.1071
6	WLS 2	4	1.0000	1.4120
7	WLS 3	1	0.7000	0.9912
7	WLS 3	2	0.9000	1.2490
7	WLS 3	3	0.9000	1.2490
7	WLS 3	4	0.7000	0.9912

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT **Transform: ARC SINE(SQUARE** ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	control	4	1.107	1.412	1.336
2	MLH 6	4	1.107	1.412	1.295
3	SUS 1	4	0.785	1.249	1.033
4	SUS 3	4	0.685	0.991	0.838
5	WLS 1	4	0.685	1.249	0.982
6	WLS 2	4	1.107	1.412	1.260
7	WLS 3	4	0.991	1.249	1.120

94 MUDPUPPY RUN#2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	control	0.023	0.152	0.076	11.41
2	MLH 6	0.022	0.147	0.073	11.35
3	SUS 1	0.038	0.196	0.098	18.97
4	SUS 3	0.031	0.177	0.088	21.11
5	WLS 1	0.062	0.248	0.124	25.26
6	WLS 2	0.031	0.176	0.088	13.97
7	WLS 3	0.022	0.149	0.074	13.29

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality

D = 0.688

W = 0.916

Critical W (P = 0.05) (n = 28) = 0.924
Critical W (P = 0.01) (n = 28) = 0.896

Data **PASS normality test at P=0.01 level**. Continue analysis.

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 1.22

Table Chi-square value = 16.81 (alpha = 0.01, df = 6)
Table Chi-square value = 12.59 (alpha = 0.05, df = 6)

Data **PASS B1 homogeneity test at 0.01 level**. Continue analysis.

94 MUDPUPPY RUN#2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	6	0.811	0.135	4.130
Within (Error)	21	0.688	0.033	
Total	27	1.499		

Critical F value = 2.57 (0.05,6,21)
Since F > Critical F REJECT Ho: All equal

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	control	1.336	0.950		
2	MLH 6	1.295	0.925	0.318	
3	SUS 1	1.033	0.725	2.365	
4	**SUS 3**	0.838	0.550	3.891	*
5	**WLS 1**	0.982	0.675	2.767	*
6	WLS 2	1.260	0.900	0.596	
7	WLS 3	1.120	0.800	1.686	

Dunnett table value = 2.46 (1 Tailed Value, P=0.05, df=20,6)

94 MUDPUPPY RUN #2 CHIRONOMIDS 10/4/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR2C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	control	4			
2	MLH 6	4	0.219	23.0	0.025
3	SUS 1	4	0.219	23.0	0.225
4	SUS 3	4	0.219	23.0	0.400
5	WLS 1	4	0.219	23.0	0.275
6	WLS 2	4	0.219	23.0	0.050
7	WLS 3	4	0.219	23.0	0.150

Critical values use k = 6, are 1 tailed, and alpha = 0.05

94 MUDPUPPY RUN #2 ADD'L *C.tentans*
6 sediments (4 replicates per sediments)
4
4
4
4
4
4
CONTROL
0.8
1.0
1.0
1.0

WLS 4
0.8
0.8
0.9
0.6

WLS 6
1.0
0.8
0.6
0.8

WLS 8
0.9
0.8
0.9
0.6

DMIR 1
0.7
0.7
0.8
0.7

DMIR 2
0.9
0.9
0.8
0.9

TITLE: 94 MUDPUPPY RUN#2 ADD'L C.TENTANS
FILE: 94MPR2CD.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 6

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.8000	1.1071
1	CONTROL	2	1.0000	1.4120
1	CONTROL	3	1.0000	1.4120
1	CONTROL	4	1.0000	1.4120
2	WLS 4	1	0.8000	1.1071
2	WLS 4	2	0.8000	1.1071
2	WLS 4	3	0.9000	1.2490
2	WLS 4	4	0.6000	0.8861
3	WLS 6	1	1.0000	1.4120
3	WLS 6	2	0.8000	1.1071
3	WLS 6	3	0.6000	0.8861
3	WLS 6	4	0.8000	1.1071
4	WLS 8	1	0.9000	1.2490
4	WLS 8	2	0.8000	1.1071
4	WLS 8	3	0.9000	1.2490
4	WLS 8	4	0.6000	0.8861
5	DMIR 1	1	0.7000	0.9912
5	DMIR 1	2	0.7000	0.9912
5	DMIR 1	3	0.8000	1.1071
5	DMIR 1	4	0.7000	0.9912
6	DMIR 2	1	0.9000	1.2490
6	DMIR 2	2	0.9000	1.2490
6	DMIR 2	3	0.8000	1.1071
6	DMIR 2	4	0.9000	1.2490

94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	1.107	1.412	1.336
2	WLS 4	4	0.886	1.249	1.087
3	WLS 6	4	0.886	1.412	1.128
4	WLS 8	4	0.886	1.249	1.123
5	DMIR 1	4	0.991	1.107	1.020
6	DMIR 2	4	1.107	1.249	1.214

94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.023	0.152	0.076	11.41
2	WLS 4	0.022	0.150	0.075	13.79
3	WLS 6	0.047	0.216	0.108	19.15
4	WLS 8	0.029	0.171	0.086	15.27
5	DMIR 1	0.003	0.058	0.029	5.69
6	DMIR 2	0.005	0.071	0.035	5.85

```
94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
---------------------------------------------------------------------

D =    0.391

W =    0.934

Critical W (P = 0.05) (n = 24) = 0.916
Critical W (P = 0.01) (n = 24) = 0.884
---------------------------------------------------------------------

Data PASS normality test at P=0.01 level. Continue analysis.


94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

---------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    5.71

---------------------------------------------------------------------
Table Chi-square value =   15.09  (alpha = 0.01, df =   5)
Table Chi-square value =   11.07  (alpha = 0.05, df =   5)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	0.242	0.048	2.233
Within (Error)	18	0.391	0.022	
Total	23	0.633		

Critical F value = 2.77 (0.05,5,18)
Since F < Critical F FAIL TO REJECT Ho: All equal

94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**
DUNNETT'S TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	1.336	0.950		
2	WLS 4	1.087	0.775	2.385	
3	WLS 6	1.128	0.800	1.994	
4	WLS 8	1.123	0.800	2.045	
5	**DMIR 1**	1.020	0.725	3.030	*
6	DMIR 2	1.214	0.875	1.174	

Dunnett table value = 2.41 (1 Tailed Value, P=0.05, df=18,5)

94 MUDPUPPY RUN#2 ADD'L C.TENTANS
File: 94MPR2CD.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	4			
2	WLS 4	4	0.164	17.3	0.175
3	WLS 6	4	0.164	17.3	0.150
4	WLS 8	4	0.164	17.3	0.150
5	DMIR 1	4	0.164	17.3	0.225
6	DMIR 2	4	0.164	17.3	0.075

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 3

Conducted by

Minnesota Pollution Control Agency
Monitoring and Assessment Section
520 Lafayette Road
St. Paul, Minnesota 55155-4194

April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of eleven of these sediment samples.

SAMPLE COLLECTION AND HANDLING

During September 22-30, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the eleven sediments referred to in this report. The composited samples were collected from the harbor using a gravity corer. The samples were stored at 4°C at the Duluth MPCA office until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Eleven sediment samples and a control sediment were subjected to the 10-day sediment toxicity test using the procedures described in U.S. EPA (1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable, mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing in Superior, WI. On the test set up day, MPCA personnel picked up the organisms from the supplier and transported them to the MPCA Toxicology Laboratory.

On October 18, 1994, eleven samples (HOB 07, HOB 08, MNS 01, MNS 03, STP 01, STP 04, SUS 05, WLS 12, WLS 13, WLS 14, and WLS 16) and the control sediment were separately homogenized by hand, and 100 mL of each sediment was placed in a test beaker (Batch #3). Each sediment test was set up with four replicates of *H. azteca* and four replicates of *C. tentans*. Approximately 100 mL of aerated, artesian well water was added to the beakers, and the sediments were allowed to settle for approximately two hours before the organisms were added. For the *C. tentans* test, ten organisms were placed in each of four beakers in a random fashion. Due to an insufficient number of *H. azteca* from the supplier, the four beakers for each sediment sample were seeded as follows: seven organisms (Control #3, HOB 07, HOB 08, MNS 01, MNS 03, STP 04, replicates A and D of WLS 12, WLS 13, WLS 14, WLS 16), six organisms (STP 01, SUS 05, replicate B of WLS 12), and five organisms for replicate C of WLS 12.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on October 28, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 100°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. The survival data were analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H. azteca* used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Due to a shortage of test organisms, only two replicates of three organisms each were set up per concentration.

RESULTS

Water Quality

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.6 to 8.3 (Table 1). The water in the *C. tentans* beakers had a pH range of 7.7 to 8.4 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 2.5 to 6.6 mg/L in the *H. azteca* beakers and from 2.0 to 6.9 mg/L in the *C. tentans* beakers (Table 2). On days five, six, seven, eight, and nine, the dissolved oxygen concentrations in the MNS 03 sediment beakers containing both *C. tentans* and *H. azteca* were less than 40% saturated. On days six, seven, and nine, the dissolved oxygen concentration in the MNS 01 beakers containing *C. tentans* were less than 40% saturated. The acceptable test range for dissolved oxygen is greater than 40% saturation (U.S. EPA, 1994). The organisms continued to be fed throughout the test.

The range of temperature values in the beakers containing *H. azteca* and *C. tentans* were both 20.5° to 23.0°C (Table 3). The recommended temperature range for these tests is 23 ± 1°C (U.S. EPA, 1994).

Test Endpoints

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 89% with a range of 86% to 100%. The survival of this control was greater than 80%, and the test passed. For the control sediment containing *C. tentans,* percent survival ranged from 30% to 80% with a mean of 52%. Survival for this control was less than 70% and, therefore, unacceptable. The *C. tentans* test failed for the batch of sediments included in this test.

Mean percent survival of *H. azteca* in the test sediments ranged from 79% in the STP 01 sediment to 100% in the HOB 08 and MNS 03 sediments. Two *H. azteca* sediment tests appeared to be mis-seeded. For WLS 16, it appears that replicate C was not seeded and replicate B was double seeded with 14 organisms. A weighted average was used to determine the mean percent survival of the three replicates which had been seeded (i.e., 93%). For WLS 12, an extra organism was found in two of the replicates; it was assumed that an error had been made in recording the initial number of organisms. A mean percent survival of 96% was calculated for WLS 12.

Mean percent survival of *C. tentans* in the test sediments ranged from 28% in the HOB 08 and MNS 01 samples to 65% in the STP 04 sample.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

Data Analysis

A one-tailed Steel's Many-one Rank test was used to test the alternative hypothesis that sample survival of *H. azteca* was less than control survival. Thus, it was not necessary to include the *H. azteca* mean percent survival data for samples which exceeded the control survival of 89%. The survival data for the control, MNS 01, and STP 01 were transformed using an arc sine-square root transformation prior to statistical analysis. Neither MNS 01 or STP 01 were toxic to *H. azteca* when compared to the control sediment ($\propto = 0.05$).

Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution

The pH of the overlying water in the reference toxicant test ranged from 8.0 to 8.4. The dissolved oxygen ranged from 7.5 to 7.9 mg/L, and the temperature of the overlying water ranged from 21.0°C to 23.0°C.

There were not enough *H. azteca* to run the standard reference toxicant test; therefore, a test with two replicates per concentration containing three organisms each was run. The test met quality assurance requirements for control survival (i.e., $\geq$ 90%) indicating that the *H. azteca* used in this test were healthy. The LC_{50} value for this test was 2.29 g/L NaCl as determined by the Trimmed Spearman-Karber method. A control chart will be developed for this test once five data points are obtained. The LC_{50} value determined from this test will be flagged since an insufficient number of organisms and replicates were run for this test.

SUMMARY

Survival of *H. azteca* in the control sediments was acceptable (i.e., greater than 80%) and none of the test sediments resulted in significantly lower survival of *H. azteca* when compared to the control survival ($\propto = 0.05$).

Control survival in the *C. tentans* test was unacceptable; therefore, the test failed. As a result, no conclusions may be drawn as to the toxicity of these sediments to *C. tentans.*

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

	Control #3		HOB 07		HOB 08		MNS 01		MNS 03		STP 01	
Day	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca
0	7.9	7.8	7.9	*	7.9	*	7.7	*	7.8	7.8	8.1	8.0
1	7.9	7.8	7.8	7.8	8.1	8.0	7.8	7.7	8.0	7.9	8.1	8.0
2	8.0	7.9	7.9	7.8	8.1	8.0	7.7	7.7	8.1	8.0	8.1	8.1
3	8.0	7.9	7.8	7.8	7.9	7.9	7.8	7.8	8.0	7.9	8.2	8.0
4	8.0	8.0	8.0	8.0	8.0	8.0	7.8	7.8	8.0	8.0	8.1	8.1
5	7.8	7.9	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.8	8.0	7.9
6	7.8	7.8	7.8	7.7	8.0	7.9	7.7	7.7	8.0	7.8	8.1	8.0
7	7.9	7.8	7.9	7.8	8.0	8.0	7.9	7.8	8.0	7.8	8.2	8.2
8	8.0	7.9	7.8	7.8	8.1	8.0	8.1	8.0	8.0	8.0	8.3	8.2
9	7.8	7.8	7.8	7.8	8.0	8.0	7.8	7.8	8.0	7.9	8.2	8.1
Range	7.8-8.0	7.8-8.0	7.8-8.0	7.7-8.0	7.8-8.1	7.9-8.0	7.7-8.1	7.7-8.0	7.8-8.1	7.8-8.0	8.0-8.3	7.9-8.2

	STP 04		SUS 05		WLS 12		WLS 13		WLS 14		WLS 16	
Day	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca	C. tentans	H. azteca
0	7.7	*	8.2	8.2	*	7.9	7.8	*	7.7	*	7.7	*
1	7.8	7.8	8.4	8.3	7.8	7.8	7.9	7.8	7.7	7.6	7.8	7.7
2	7.8	7.8	8.3	8.3	7.8	7.8	7.9	7.9	7.8	7.8	7.8	7.7
3	7.8	7.8	8.1	8.2	7.8	7.8	7.9	7.8	7.8	7.7	7.8	7.7
4	7.8	7.8	8.1	8.1	7.9	7.8	8.0	7.9	7.9	7.8	7.9	7.8
5	7.8	7.9	7.8	8.0	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.8
6	7.8	7.8	8.0	8.1	7.8	7.8	8.0	7.9	7.9	7.8	7.9	7.8
7	8.0	7.9	8.3	8.2	7.9	7.8	8.0	8.0	8.0	7.9	7.9	7.8
8	8.1	8.0	8.2	8.3	7.9	7.9	8.0	8.0	8.1	8.0	8.1	8.0
9	7.9	7.9	8.2	8.2	7.8	7.8	7.9	8.0	7.9	7.9	7.9	7.9
Range	7.7-8.1	7.8-8.0	7.8-8.4	8.0-8.3	7.8-7.9	7.8-7.9	7.8-8.0	7.8-8.0	7.7-8.1	7.6-8.0	7.7-8.1	7.7-8.0

* No measurement was taken because, given the short amount of time that had passed since the organisms were placed in the beakers, it was assumed that the difference in water quality between this and the other beaker for this sediment was negligible.

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

	Control #3		HOB 07		HOB 08		MNS 01		MNS 03		STP 01	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	6.2	*	*	6.5	*	6.5	6.4	*	6.8	6.6	6.7	6.6
1	5.4	5.7	5.5	5.5	5.8	5.3	5.2	5.2	5.1	5.4	5.4	5.7
2	5.5	5.8	5.5	5.9	4.9	5.7	4.6	5.2	4.2	5.1	5.1	5.6
3	5.3	5.2	4.2	4.9	4.5	4.6	4.3	5.2	4.0	3.9	4.7	5.1
4	5.0	5.6	5.1	5.5	4.5	5.2	4.3	5.1	4.0	4.8	4.8	5.5
5	5.5	6.2	4.7	6.0	4.6	5.5	4.3	5.1	2.4	2.9	4.8	5.7
6	4.9	5.6	4.0	5.1	4.4	5.4	3.6	5.4	3.0	2.5	4.4	5.2
7	4.6	5.7	3.9	4.8	4.0	5.4	3.3	5.4	2.1	3.1	4.9	6.2
8	5.3	5.8	4.6	5.0	4.5	6.0	4.1	5.7	2.4	3.0	5.8	6.5
9	4.2	5.0	3.5	4.5	4.0	5.0	3.0	4.9	2.0	3.4	4.7	5.7
Range	4.2-6.2	5.2-6.2	3.5-5.5	4.5-6.5	4.0-5.8	4.6-6.5	3.0-6.4	4.9-5.7	2.0-6.8	2.5-6.6	4.4-6.7	5.1-6.6

	STP 04		SUS 05		WLS 12		WLS 13		WLS 14		WLS 16	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	6.2	*	6.8	6.6	6.9	*	*	6.4	*	6.0	*	6.4
1	5.5	5.8	6.1	6.3	5.7	5.7	5.4	5.8	4.9	4.9	5.5	5.2
2	5.6	5.8	5.1	5.9	5.2	5.8	5.3	5.7	5.1	5.1	5.6	5.9
3	4.9	4.8	5.5	5.6	4.1	5.4	4.2	4.8	4.2	4.4	4.7	4.7
4	5.3	5.7	5.0	5.4	5.2	5.8	5.0	5.8	4.7	5.3	5.2	5.5
5	5.1	5.7	4.5	5.8	5.2	5.7	4.7	5.2	5.0	5.5	4.9	5.4
6	4.5	5.4	4.2	5.0	3.5	5.1	4.5	5.4	4.4	5.2	4.5	5.3
7	4.2	5.6	5.0	5.4	4.4	5.4	4.5	5.5	4.7	5.3	4.5	5.0
8	5.5	6.0	4.6	5.6	4.6	5.9	4.6	5.6	5.5	5.5	5.0	5.5
9	3.9	4.8	4.7	5.2	4.3	5.1	4.1	5.3	4.5	5.3	4.4	5.1
Range	3.9-6.2	4.8-6.0	4.2-6.8	5.0-6.6	3.5-6.9	5.1-5.9	4.1-5.4	4.8-6.4	4.2-5.5	4.4-6.0	4.4-5.6	4.7-6.4

* No measurement was taken because, given the short amount of time that had passed since the organisms were placed in the beakers, it was assumed that the difference in water quality between this and the other beaker for this sediment was negligible.

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control #3		HOB 07		HOB 08		MNS 01		MNS 03		STP 01	
	C. tentans	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
Day												
0	22.5	22.5	22.5	22.5	*	22.5	22.5	*	22.5	22.5	22.5	22.5
1	22.5	22.5	22.5	22.5	23.0	23.0	23.0	23.0	22.5	22.5	22.5	22.5
2	22.5	22.5	22.0	22.0	23.0	23.0	22.5	22.5	22.0	22.0	22.5	22.5
3	22.0	22.0	22.0	22.0	22.5	22.5	22.0	22.0	22.0	22.0	22.0	22.0
4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
5	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
6	21.0	21.0	21.0	21.0	21.5	21.5	21.5	21.5	20.5	20.5	21.0	21.0
7	20.5	20.5	20.5	20.5	21.0	21.0	21.0	21.0	20.5	20.5	20.5	20.5
8	20.5	20.5	20.5	20.5	21.0	21.0	21.0	21.0	20.5	20.5	20.5	20.5
9	22.5	22.5	22.5	22.5	22.5	22.5	22.0	22.0	22.5	22.5	22.5	22.5
Range	20.5-22.5	20.5-22.5	20.5-22.5	20.5-22.5	21.0-23.0	21.0-23.0	21.0-23.0	21.0-23.0	20.5-22.5	20.5-22.5	20.5-22.5	20.5-22.5

Sample	STP 04		SUS 05		WLS 12		WLS 13		WLS 14		WLS 16	
	C. tentans	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
Day												
0	22.5	*	23.0	23.0	22.5	*	22.5	*	22.5	*	22.5	*
1	23.0	23.0	23.0	23.0	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0
2	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
3	22.0	22.0	22.5	22.5	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
5	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
6	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
7	21.0	21.0	21.0	21.0	20.5	20.5	21.0	21.0	21.0	21.0	21.0	21.0
8	21.0	21.0	21.0	21.0	20.5	20.5	21.0	21.0	21.0	21.0	21.0	21.0
9	22.0	22.0	22.5	22.5	22.5	22.5	22.5	22.0	22.0	22.0	22.0	22.0
Range	21.0-23.0	21.0-23.0	21.0-23.0	21.0-23.0	20.5-22.5	20.5-22.5	21.0-23.0	21.0-23.0	21.0-23.0	21.0-23.0	21.0-23.0	21.0-23.0

* No measurement was taken because, given the short amount of time that had passed since the organisms were placed in the beakers, it was assumed that the difference in water quality between this and the other beaker for this sediment was negligible.

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

Batch #3	Mean Percent Survival	
	Hyalella azteca	*Chironomus tentans**
CONTROL #3	89%	52%
HOB 07	96%	60%
HOB 08	100%	28%
MNS 01	89%	28%
MNS 03	100%	30%
STP 01	79%	58%
STP 04	96%	65%
SUS 05	96%	40%
WLS 12	96%	58%
WLS 13	96%	45%
WLS 14	96%	50%
WLS 16	93%	42%

*Control survival was unacceptable for *C. tentans* (i.e., <70% survival). Thus, the *C. tentans* tests failed for this batch of sediments.

APPENDIX A

Statistical Analyses

94 MUDPUPPY RUN #3 HYALELLA
3 sediments (4 replicates per sediment)

CONTROL
0.86000000
0.86000000
0.86000000
1.00000000

MNS 1
1.00000000
1.00000000
0.57000000
1.00000000

STP 1
1
1
1
0.17

TITLE: 94 MUDPUPPY RUN #3 HYALELLA
FILE: 94MUD3.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 3

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.8600	1.1873
1	CONTROL	2	0.8600	1.1873
1	CONTROL	3	0.8600	1.1873
1	CONTROL	4	1.0000	1.4120
2	MNS 1	1	1.0000	1.4120
2	MNS 1	2	1.0000	1.4120
2	MNS 1	3	0.5700	0.8556
2	MNS 1	4	1.0000	1.4120
3	STP 1	1	1.0000	1.4120
3	STP 1	2	1.0000	1.4120
3	STP 1	3	1.0000	1.4120
3	STP 1	4	0.1700	0.4250

94 MUDPUPPY RUN #3 HYALELLA
File: 94MUD3.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	1.187	1.412	1.243
2	MNS 1	4	0.856	1.412	1.273
3	STP 1	4	0.425	1.412	1.165

94 MUDPUPPY RUN #3 HYALELLA
File: 94MUD3.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.013	0.112	0.056	9.04
2	MNS 1	0.077	0.278	0.139	21.85
3	STP 1	0.244	0.494	0.247	42.35

94 MUDPUPPY RUN #3 HYALELLA
File: 94MUD3.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Shapiro - Wilk's test for normality

D = 1.001

W = 0.784

Critical W (P = 0.05) (n = 12) = 0.859
Critical W (P = 0.01) (n = 12) = 0.805

Data FAIL normality test. Try another transformation.

Warning: The first three homogeneity tests are sensitive to non-normal data and should not be performed.

94 MUDPUPPY RUN #3 HYALELLA
File: 94MUD3.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

Bartlett's test for homogeneity of variance
Calculated B1 statistic = 4.58

Table Chi-square value = 9.21 (alpha = 0.01, df = 2)
Table Chi-square value = 5.99 (alpha = 0.05, df = 2)

Data **PASS B1 homogeneity test at 0.01 level**. Continue analysis.

94 MUDPUPPY RUN #3 HYALELLA
File: 94MUD3.DAT **Transform: ARC SINE(SQUARE ROOT(Y))**

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.243				
2	MNS 1	1.273	20.50	11.00	4.00	
3	STP 1	1.165	20.50	11.00	4.00	

Critical values use k = 2, are 1 tailed, and alpha = 0.05

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 4

Conducted by

Minnesota Pollution Control Agency
Monitoring and Assessment Section
520 Lafayette Road
St. Paul, Minnesota 55155-4194

April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of six of these sediment samples.

SAMPLE COLLECTION AND HANDLING

During September 28-29, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the six sediments referred to in this report. The composited samples were collected from the harbor using a gravity corer. The samples were stored at 4°C at the Duluth MPCA office until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Six sediment samples and a control sediment were subjected to the 10-day sediment toxicity test using the procedures described in U.S. EPA (1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable, mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing (Superior, WI) prior to the test set up.

On November 1, 1994, six samples (HOB 10, HOB 11, HOB 12, HOB 13, HOB 14, and HOB 15) and the control sediment were separately homogenized by hand, and 100 mL of each sediment was placed in a test beaker (Batch #4). Each sediment test was set up with four replicates of *H. azteca* and four replicates of *C. tentans*. Approximately 100 mL of aerated, artesian well water was added to the beakers, and the sediments were allowed to settle for approximately two hours before the organisms were added. For each sediment, ten organisms were placed in each of eight beakers in a random fashion.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on November 11, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 100°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. The survival data were analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H. azteca* used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Three replicates of five organisms each were set up per concentration.

RESULTS

Water Quality

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.4 to 8.2 (Table 1). The water in the *C. tentans* beakers had a pH range of 7.5 to 8.1 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 3.8 to 6.7 mg/L in the *H. azteca* beakers and from 2.2 to 6.4 mg/L in the *C. tentans* beakers (Table 2). It should be noted that on Days 3, 5, 8 and 9, the dissolved oxygen concentration of the *C. tentans* beakers containing samples HOB 13, HOB 14, and HOB 15 was unacceptable (i.e., less than 40% saturated). Also, on Day 6, the dissolved oxygen concentration of the water in the *C. tentans* beaker of HOB 14 was unacceptable, as it was on Day 7 in the *C. tentans* beakers of HOB 13 and HOB 15. The organisms continued to be fed throughout the test.

The temperature of the overlying water in each glass box was measured and ranged from 20.5°C to 23.0°C in both tests (Table 3). The recommended temperature for these tests is 23 ± 1°C (U.S. EPA, 1994).

<u>Test Endpoints</u>

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 88% with a range of 80% to 100%. For the control sediment containing *C. tentans,* percent survival ranged from 80% to 90% with a mean of 88%. Survival for these controls was acceptable, and both tests passed.

Mean percent survival of *H. azteca* in the test sediments ranged from 52% in the HOB 13 sediment to 95% in the HOB 10 sediment. Mean percent survival of *C. tentans* in the test sediments ranged from 70% in the HOB 11 and HOB 12 samples to 80% in the HOB 10, HOB 14, and HOB 15 samples.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

<u>Data Analysis</u>

All data were transformed using an arc sine-square root transformation before being subjected to statistical analysis. A one-tailed statistical test was used to test the alternative hypothesis that sample survival was less than control survival. For *H. azteca,* Dunnett's test was used to determine that HOB 12 and HOB 13 had significantly lower survival than the control ($p = 0.05$). For *C. tentans,* a nonparametric statistical test (i.e., Steel's Many-one Rank test) had to be used due to 0% variance in the HOB 14 replicates. None of the *C. tentans* test sediments were toxic compared to the control sediment ($\alpha = 0.05$). The statistical analysis of these data is included in Appendix A.

Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test vessels for this test were made daily for the tests 96-hour duration. A daily count of surviving organisms in each vessel was also made.

The pH of the overlying water in the reference toxicant test ranged from 8.1 to 8.5. The dissolved oxygen ranged from 7.6 to 8.3 mg/L, and the temperature of the overlying water ranged from 20.0°C to 21.8°C. The mean percent survival of the organisms in the control was greater than 90% (i.e., 100%) which was acceptable.

The LC_{50} for this reference toxicant test was 3.80 g/L NaCl as determined by the Trimmed Spearman-Karber method. A control chart will be developed for this test once five data points are obtained.

SUMMARY

Control survival of *H. azteca* in both the reference toxicant test and the sediment test was acceptable (i.e., greater than 90% and 80%, respectively). Survival of *H. azteca* in the test sediments was statistically less than the control ($p = 0.05$) in only two samples: HOB 12 and HOB 13.

Control survival in the *C. tentans* test was acceptable (i.e., greater than 70%). Survival of *C. tentans* in all of the test sediments was not significantly less than that of the control ($\alpha = 0.05$).

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

Day	Control #4 *C. tentans*	Control #4 *H. azteca*	HOB 10 *C. tentans*	HOB 10 *H. azteca*	HOB 11 *C. tentans*	HOB 11 *H. azteca*	HOB 12 *C. tentans*	HOB 12 *H. azteca*
0	7.6	7.7	7.8	7.8	7.7	7.8	7.8	7.8
1	8.0	8.1	8.0	8.0	7.9	8.0	8.1	8.2
2	8.0	8.2	8.0	8.0	7.9	7.9	8.1	8.2
3	7.8	7.8	7.7	7.7	7.7	7.8	7.8	7.9
4	7.9	8.0	8.0	8.0	7.9	8.0	8.0	8.1
5	7.7	7.7	7.9	7.9	7.8	7.8	7.5	7.4
6	7.9	8.0	7.9	8.0	7.8	7.9	8.0	8.1
7	7.9	8.0	7.9	7.9	7.8	7.9	8.0	8.2
8	7.9	8.1	7.9	8.0	7.7	7.8	8.0	8.0
9	7.9	8.1	7.8	7.9	7.9	8.0	8.1	8.2
Range	7.6-8.0	7.7-8.2	7.7-8.0	7.7-8.0	7.7-7.9	7.8-8.0	7.5-8.1	7.4-8.2

Day	HOB 13 *C. tentans*	HOB 13 *H. azteca*	HOB 14 *C. tentans*	HOB 14 *H. azteca*	HOB 15 *C. tentans*	HOB 15 *H. azteca*
0	7.7	7.7	7.9	8.0	7.8	7.7
1	7.9	8.0	7.9	8.1	7.9	8.0
2	8.0	8.0	7.9	8.0	7.9	8.0
3	7.6	7.7	7.6	7.6	7.6	7.6
4	7.8	8.0	7.9	8.0	7.9	8.0
5	7.9	7.9	7.9	8.0	8.0	8.0
6	7.8	7.9	7.9	8.0	7.9	7.9
7	7.9	8.0	7.9	8.0	8.0	8.0
8	7.8	8.0	7.9	8.0	7.9	8.0
9	7.8	7.9	7.8	8.0	7.9	8.0
Range	7.6-8.0	7.7-8.0	7.6-7.9	7.6-8.1	7.6-8.0	7.6-8.0

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

Day	Control #4 *C. tentans*	Control #4 *H. azteca*	HOB 10 *C. tentans*	HOB 10 *H. azteca*	HOB 11 *C. tentans*	HOB 11 *H. azteca*	HOB 12 *C. tentans*	HOB 12 *H. azteca*
0	*	5.6	*	6.4	*	6.1	6.4	6.7
1	5.8	6.2	5.9	6.4	5.8	6.3	6.0	6.6
2	5.1	6.6	5.6	6.2	5.4	6.6	5.0	6.5
3	5.1	6.5	5.0	6.1	5.0	6.0	5.5	6.2
4	5.5	6.4	5.9	6.2	5.2	6.1	5.3	6.4
5	4.0	6.1	4.0	5.9	3.7	5.7	4.1	5.3
6	3.7	5.2	4.7	5.8	4.1	5.2	4.6	5.8
7	4.5	5.4	4.7	5.7	4.3	5.3	4.6	5.7
8	4.2	5.5	4.3	5.8	4.0	5.3	4.0	5.7
9	4.4	5.8	4.1	5.6	3.5	5.3	4.3	6.1
Range	3.7-5.8	5.2-6.6	4.0-5.9	5.6-6.4	3.5-5.8	5.2-6.6	4.0-6.4	5.3-6.7

Day	HOB 13 *C. tentans*	HOB 13 *H. azteca*	HOB 14 *C. tentans*	HOB 14 *H. azteca*	HOB 15 *C. tentans*	HOB 15 *H. azteca*
0	*	6.0	*	6.5	*	6.0
1	5.7	6.2	5.2	6.2	5.5	6.0
2	4.8	5.2	4.2	5.3	4.4	5.4
3	3.2	3.8	3.0	4.4	2.8	4.5
4	3.6	4.7	3.6	5.1	4.5	5.5
5	3.1	4.2	2.2	4.7	3.2	4.7
6	3.9	5.3	3.3	5.2	3.6	5.2
7	3.4	5.1	3.8	5.0	3.3	5.2
8	3.0	4.6	3.0	4.9	2.9	4.5
9	2.9	4.7	3.1	5.1	3.1	4.7
Range	2.9-5.7	3.8-6.2	2.2-5.2	4.4-6.5	2.8-5.5	4.5-6.0

* No measurement was taken because given the short amount of time that had passed since the organisms were placed in the beakers, it was assumed that the difference in water quality between this and the other beaker for this sediment was negligible.

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control #4		HOB 10		HOB 11		HOB 12	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	21.0	21.0	21.5	21.5	21.0	21.0	21.5	21.5
1	21.5	21.5	21.5	21.5	21.5	21.5	22.0	22.0
2	21.5	21.5	21.0	21.0	21.0	21.0	21.5	21.5
3	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
4	22.5	22.5	22.0	22.0	22.0	22.0	23.0	23.0
5	23.0	23.0	22.0	22.0	23.0	23.0	23.0	23.0
6	21.5	21.5	21.5	21.5	21.5	21.5	22.0	22.0
7	21.0	21.0	21.0	21.0	21.0	21.0	21.5	21.5
8	21.0	21.0	20.5	20.5	21.0	21.0	21.0	21.0
9	20.7	20.7	20.8	20.8	20.8	20.8	21.0	21.0
Range	20.7-23.0	20.7-23.0	20.5-22.0	20.5-22.0	20.8-23.0	20.8-23.0	21.0-23.0	21.0-23.0

	HOB 13		HOB 14		HOB 15	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	21.5	21.5	21.5	21.5	21.5	21.5
1	21.5	21.5	22.5	22.5	21.5	21.5
2	21.0	21.0	22.0	22.0	21.0	21.0
3	21.0	21.0	21.0	21.0	21.0	21.0
4	22.0	22.0	23.0	23.0	22.5	22.5
5	22.0	22.0	23.0	23.0	23.0	23.0
6	21.5	21.5	22.0	22.0	21.5	21.5
7	21.0	21.0	22.0	22.0	21.0	21.0
8	20.5	20.5	21.5	21.5	20.5	20.5
9	20.6	20.6	21.5	21.5	20.8	20.8
Range	20.5-22.0	20.5-22.0	21.0-23.0	21.0-23.0	20.5-23.0	20.5-23.0

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

	Mean Percent Survival	
Batch #4	***Hyalella azteca***	***Chironomus tentans***
Control #4	88%	88%
HOB 10	95%	80%
HOB 11	68%	70%
HOB 12	55%*	70%
HOB 13	52%*	72%
HOB 14	85%	80%
HOB 15	78%	80%

* Significantly less survival than the control, p=0.05.

APPENDIX A

Statistical Analyses

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
7
4
4
4
4
4
4
4
CONTROL
1.0
0.8
0.9
0.8
HOB 10
1.0
0.8
1.0
1.0
HOB 11
0.5
0.6
0.8
0.8
HOB 12
0.4
0.4
0.7
0.7
HOB 13
0.1
0.6
0.6
0.8
HOB 14
0.9
0.9
1.0
0.6
HOB 15
0.7
0.7
0.9
0.8

```
94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
----------------------------------------------------------------------

D =    0.837

W =    0.950

Critical W (P = 0.05) (n = 28) = 0.924
Critical W (P = 0.01) (n = 28) = 0.896
----------------------------------------------------------------------

Data PASS normality test at P=0.01 level. Continue analysis.


94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

----------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    4.15

----------------------------------------------------------------------
Table Chi-square value =   16.81  (alpha = 0.01, df =   6)
Table Chi-square value =   12.59  (alpha = 0.05, df =   6)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

TITLE: 94 MUDPUPPY RUN #4 HYALELLA 11/01/94
FILE: 94MPR4H.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 7

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	1.0000	1.4120
1	CONTROL	2	0.8000	1.1071
1	CONTROL	3	0.9000	1.2490
1	CONTROL	4	0.8000	1.1071
2	HOB 10	1	1.0000	1.4120
2	HOB 10	2	0.8000	1.1071
2	HOB 10	3	1.0000	1.4120
2	HOB 10	4	1.0000	1.4120
3	HOB 11	1	0.5000	0.7854
3	HOB 11	2	0.6000	0.8861
3	HOB 11	3	0.8000	1.1071
3	HOB 11	4	0.8000	1.1071
4	HOB 12	1	0.4000	0.6847
4	HOB 12	2	0.4000	0.6847
4	HOB 12	3	0.7000	0.9912
4	HOB 12	4	0.7000	0.9912
5	HOB 13	1	0.1000	0.3218
5	HOB 13	2	0.6000	0.8861
5	HOB 13	3	0.6000	0.8861
5	HOB 13	4	0.8000	1.1071
6	HOB 14	1	0.9000	1.2490
6	HOB 14	2	0.9000	1.2490
6	HOB 14	3	1.0000	1.4120
6	HOB 14	4	0.6000	0.8861
7	HOB 15	1	0.7000	0.9912
7	HOB 15	2	0.7000	0.9912
7	HOB 15	3	0.9000	1.2490
7	HOB 15	4	0.8000	1.1071

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT   Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	1.107	1.412	1.219
2	HOB 10	4	1.107	1.412	1.336
3	HOB 11	4	0.785	1.107	0.971
4	HOB 12	4	0.685	0.991	0.838
5	HOB 13	4	0.322	1.107	0.800
6	HOB 14	4	0.886	1.412	1.199
7	HOB 15	4	0.991	1.249	1.085

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT   Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.021	0.145	0.073	11.91
2	HOB 10	0.023	0.152	0.076	11.41
3	HOB 11	0.026	0.162	0.081	16.68
4	HOB 12	0.031	0.177	0.088	21.11
5	HOB 13	0.113	0.336	0.168	41.94
6	HOB 14	0.049	0.222	0.111	18.54
7	HOB 15	0.015	0.122	0.061	11.29

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	6	0.983	0.164	4.112
Within (Error)	21	0.837	0.040	
Total	27	1.820		

Critical F value = 2.57 (0.05,6,21)
Since F > Critical F REJECT Ho: All equal

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2
Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	1.219	0.875		
2	HOB 10	1.336	0.950	-0.829	
3	HOB 11	0.971	0.675	1.753	
4	HOB 12	0.838	0.550	2.699	*
5	HOB 13	0.800	0.525	2.966	*
6	HOB 14	1.199	0.850	0.140	
7	HOB 15	1.085	0.775	0.951	

Dunnett table value = 2.46 (1 Tailed Value, P=0.05, df=20,6)

94 MUDPUPPY RUN #4 HYALELLA 11/01/94
File: 94MPR4H.DAT Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	4			
2	HOB 10	4	0.295	33.8	-0.075
3	HOB 11	4	0.295	33.8	0.200
4	HOB 12	4	0.295	33.8	0.325
5	HOB 13	4	0.295	33.8	0.350
6	HOB 14	4	0.295	33.8	0.025
7	HOB 15	4	0.295	33.8	0.100

94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
7
4
4
4
4
4
4
4
CONTROL
0.80000000
0.90000000
0.90000000
0.90000000
HOB 10
1.00000000
0.40000000
0.90000000
0.90000000
HOB 11
0.50000000
0.60000000
0.90000000
0.80000000
HOB 12
0.80000000
0.70000000
0.80000000
0.50000000
HOB 13
0.80000000
0.80000000
0.40000000
0.90000000
HOB 14
0.8
0.80000000
0.8
0.80000000
HOB 15
0.7
0.8
0.9
0.8

```
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
----------------------------------------------------------------------

D =    0.734

W =    0.917

Critical W (P = 0.05) (n = 28) = 0.924
Critical W (P = 0.01) (n = 28) = 0.896
----------------------------------------------------------------------

Data PASS normality test at P=0.01 level. Continue analysis.



94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

Hartley's test for homogeneity of variance
Bartlett's test for homogeneity of variance
----------------------------------------------------------------------

These two tests can not be performed because at least one group has
zero variance.

Data FAIL to meet homogeneity of variance assumption.
Additional transformations are useless.

----------------------------------------------------------------------
```

TITLE: 94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
FILE: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 7

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.8000	1.1071
1	CONTROL	2	0.9000	1.2490
1	CONTROL	3	0.9000	1.2490
1	CONTROL	4	0.9000	1.2490
2	HOB 10	1	1.0000	1.4120
2	HOB 10	2	0.4000	0.6847
2	HOB 10	3	0.9000	1.2490
2	HOB 10	4	0.9000	1.2490
3	HOB 11	1	0.5000	0.7854
3	HOB 11	2	0.6000	0.8861
3	HOB 11	3	0.9000	1.2490
3	HOB 11	4	0.8000	1.1071
4	HOB 12	1	0.8000	1.1071
4	HOB 12	2	0.7000	0.9912
4	HOB 12	3	0.8000	1.1071
4	HOB 12	4	0.5000	0.7854
5	HOB 13	1	0.8000	1.1071
5	HOB 13	2	0.8000	1.1071
5	HOB 13	3	0.4000	0.6847
5	HOB 13	4	0.9000	1.2490
6	HOB 14	1	0.8000	1.1071
6	HOB 14	2	0.8000	1.1071
6	HOB 14	3	0.8000	1.1071
6	HOB 14	4	0.8000	1.1071
7	HOB 15	1	0.7000	0.9912
7	HOB 15	2	0.8000	1.1071
7	HOB 15	3	0.9000	1.2490
7	HOB 15	4	0.8000	1.1071

94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	1.107	1.249	1.214
2	HOB 10	4	0.685	1.412	1.149
3	HOB 11	4	0.785	1.249	1.007
4	HOB 12	4	0.785	1.107	0.998
5	HOB 13	4	0.685	1.249	1.037
6	HOB 14	4	1.107	1.107	1.107
7	HOB 15	4	0.991	1.249	1.114

94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.005	0.071	0.035	5.85
2	HOB 10	0.102	0.319	0.159	27.75
3	HOB 11	0.044	0.210	0.105	20.86
4	HOB 12	0.023	0.152	0.076	15.21
5	HOB 13	0.060	0.244	0.122	23.55
6	HOB 14	0.000	0.000	0.000	0.00
7	HOB 15	0.011	0.106	0.053	9.48

94 MUDPUPPY RUN #4 CHIRONOMIDS 11/01/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR4C.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.214				
2	HOB 10	1.149	19.00	10.00	4.00	
3	HOB 11	1.007	13.00	10.00	4.00	
4	HOB 12	0.998	11.00	10.00	4.00	
5	HOB 13	1.037	13.50	10.00	4.00	
6	HOB 14	1.107	12.00	10.00	4.00	
7	HOB 15	1.114	13.50	10.00	4.00	

Critical values use k = 6, are 1 tailed, and alpha = 0.05

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 5

Conducted by

Minnesota Pollution Control Agency
Monitoring and Assessment Section
520 Lafayette Road
St. Paul, Minnesota 55155-4194

April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the *C. tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of six of these sediment samples.

SAMPLE COLLECTION AND HANDLING

During October 3-4, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the six sediments referred to in this report. The samples were collected from the harbor using a gravity corer. The samples were stored at 4°C at the Duluth MPCA office until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Six sediment samples and a control sediment were subjected to the 10-day sediment toxicity test using the procedures described in U.S. EPA (1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable, mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing (Superior, WI) prior to the test set up.

On November 11, 1994, six samples (ERP 03, KMB 04, KMB 05, STP 06, STP 07, and SUS 07) and the control sediment were separately homogenized by hand, and 100 mL of each sediment was placed in a test beaker (Batch #5). Approximately 100 mL of aerated, artesian well water was added to each beaker, and the sediments were allowed to settle for approximately two hours before the organisms were added. Each sediment was set up with four replicates of *H. azteca* and four replicates of *C. Tentans.* For each sediment, ten organisms were placed in each beaker in a random fashion.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on November 21, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 100°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. Usually, the resulting data are analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, the controls failed for both of these tests which invalidated the survival data. Due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H.* azteca used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Three replicates of five organisms each were set up per concentration.

RESULTS

<u>Water Quality</u>

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.2 to 8.5 (Table 1). The water in the *C. tentans* beakers had a pH range of 7.4 to 8.4 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 2.8 to 6.9 mg/L in the *H. azteca* beakers and from 1.8 to 6.7 mg/L in the *C. tentans* beakers (Table 2). It should be noted that on Days 4, 7, 8, and 9, the dissolved oxygen concentration in the STP 06 sediment beaker containing *C. tentans* was less than 40% saturated, which is out of the acceptable test range for dissolved oxygen. On Days 4, 5, 7, and 8, the dissolved oxygen concentration in the *H. azteca* beaker of STP 06 was below the acceptable concentration. The organisms continued to be fed throughout the test.

The temperature of the overlying water in each glass box was measured and ranged from 20.5°C to 23.0 °C in both tests (Table 3). The recommended temperature for these tests is 23 ± 1°C (U.S. EPA, 1994).

Test Endpoints

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 78% with a range of 70% to 100%. For the control sediment containing *C. tentans,* percent survival ranged from 50% to 90% with a mean of 68%. Survival for these controls was less than the required mean percent survival of 80% and 70%, respectively. Therefore, both tests failed.

Mean percent survival of *H. azteca* in the test sediments ranged from 45% in the SUS 07 sediment to 80% in the ERP 03 and KMB 05 sediments. Mean percent survival of *C. tentans* in the test sediments ranged from 0% in the SUS 07 sample to 68% in the STP 06 and STP 07 samples.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

Data Analysis

Since both controls failed, the data for these tests were not analyzed.

Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution

The pH of the overlying water in the reference toxicant test ranged from 8.1 to 8.6. The dissolved oxygen ranged from 6.8 to 8.1 mg/L, and the temperature of the overlying water ranged from 20°C to 21°C (temperature was recorded only the first 70 hours of the test). Survival of the organisms in the control was greater than 90% (i.e., 93%) which was acceptable.

The LC_{50} for this reference toxicant test was 4.83 g/L NaCl as determined by the Trimmed Spearman-Karber method. A control chart will be developed for this test once five data points are obtained.

SUMMARY

Survival of the *H. azteca* in the reference toxicant test was acceptable (i.e., greater than 90%), indicating that the *H. azteca* organisms used in the toxicity test were healthy. However, survival of *H. azteca* in the control sediments was unacceptable (i.e., less than 80%). Therefore, the toxicity test failed.

Control survival was unacceptable in the *C. tentans* test (i.e., less than 70%), resulting in the failure of this test.

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

	Control #5		ERP 03		KMB 04		KMB 05	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	8.0	8.0	7.9	8.0	7.7	7.8	7.9	8.0
1	7.8	7.8	7.8	7.8	7.9	7.9	7.8	7.8
2	7.9	7.9	7.8	7.8	7.9	7.9	7.8	7.8
3	8.1	8.2	8.1	8.1	8.4	8.5	7.8	8.0
4	8.0	8.1	8.1	8.2	8.0	8.1	8.0	7.9
5	8.1	8.0	8.0	8.1	8.0	8.1	7.9	8.0
6	7.9	8.0	8.0	8.0	8.0	8.3	7.8	7.9
7	7.9	7.9	7.9	7.8	7.9	8.0	7.8	7.9
8	7.6	7.7	7.7	7.7	7.5	7.4	7.5	7.6
9	7.8	8.0	*	*	7.7	7.9	*	*
Range	7.6-8.1	7.7-8.2	7.7-8.1	7.7-8.2	7.5-8.4	7.4-8.5	7.5-7.9	7.6-8.0

	STP 06		STP 07		SUS 07	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	7.8	7.9	7.9	8.0	7.4	7.2
1	7.9	7.9	7.8	7.8	8.2	8.1
2	7.9	7.9	7.8	7.8	8.0	8.1
3	8.2	8.3	8.1	8.2	8.4	8.4
4	7.9	8.0	8.0	8.0	8.2	7.8
5	7.8	8.0	8.0	8.2	8.2	8.2
6	8.0	8.0	8.0	8.0	8.2	8.1
7	7.9	7.9	7.8	7.7	8.1	8.2
8	7.7	7.6	7.6	7.6	7.7	7.4
9	7.8	7.9	*	8.0	7.9	7.7
Range	7.7-8.2	7.6-8.3	7.6-8.1	7.6-8.2	7.4-8.4	7.2-8.4

* pH meter was dropped and reading was questionable.

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

Day	Control #5 *C. tentans*	Control #5 *H. azteca*	ERP 03 *C. tentans*	ERP 03 *H. azteca*	KMB 04 *C. tentans*	KMB 04 *H. azteca*	KMB 05 *C. tentans*	KMB 05 *H. azteca*
0	6.7	6.7	6.4	6.4	6.2	6.1	6.7	6.9
1	5.8	6.2	5.8	6.2	6.3	6.0	4.6	5.0
2	5.5	5.8	5.9	6.2	6.0	6.2	6.0	6.1
3	5.9	6.0	6.1	5.8	5.8	5.9	6.0	6.0
4	5.5	6.0	6.3	5.6	6.1	6.1	6.2	5.7
5	5.9	5.5	6.4	5.6	6.2	5.2	6.1	5.7
6	5.7	5.4	5.9	6.3	5.9	5.1	6.1	5.7
7	5.1	5.0	5.6	5.6	5.3	4.6	5.0	5.0
8	4.4	4.4	3.8	4.4	4.4	4.0	4.3	4.9
9	3.8	4.3	5.2	5.1	4.1	4.3	4.3	4.4
Range	3.8-6.7	4.3-6.7	3.8-6.4	4.4-6.4	4.1-6.3	4.0-6.2	4.3-6.7	4.4-6.9

Day	STP 06 *C. tentans*	STP 06 *H. azteca*	STP 07 *C. tentans*	STP 07 *H. azteca*	SUS 07 *C. tentans*	SUS 07 *H. azteca*
0	6.6	6.7	6.5	6.8	4.2	3.8
1	5.3	5.6	5.4	5.5	4.2	5.3
2	5.7	6.0	6.0	6.2	5.0	5.5
3	4.1	4.0	6.0	6.1	5.2	4.3
4	3.0	2.8	6.3	5.9	5.3	5.6
5	4.6	3.2	5.9	5.6	4.7	5.2
6	4.0	3.9	5.9	5.4	5.6	5.5
7	2.9	3.2	5.3	5.1	5.3	5.4
8	2.6	3.2	4.2	4.7	4.4	5.2
9	1.8	4.3	4.2	5.0	5.0	4.9
Range	1.8-6.6	2.8-6.7	4.2-6.5	4.7-6.8	4.2-5.6	3.8-5.6

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control #5		ERP 03		KMB 04		KMB 05	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	21.8	21.8	21.5	21.5	20.5	20.5	21.5	21.5
1	21.0	21.0	21.0	21.0	21.5	21.5	21.0	21.0
2	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
3	21.5	21.5	21.8	21.8	21.8	21.8	21.5	21.5
4	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
5	20.8	20.8	21.0	21.0	21.0	21.0	21.0	21.0
6	21.2	21.2	21.5	21.5	21.5	21.5	21.5	21.5
7	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
8	21.5	21.5	21.5	21.5	22.0	22.0	22.0	22.0
9	22.5	22.5	22.5	22.5	23.0	23.0	22.5	22.5
Range	20.8-22.5	20.8-22.5	21.0-22.5	21.0-22.5	20.5-23.0	20.5-23.0	21.0-22.5	21.0-22.5

	STP 06		STP 07		SUS 07	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	21.0	21.0	21.5	21.5	21.0	21.0
1	21.0	21.0	21.0	21.0	21.5	21.5
2	21.0	21.0	21.0	21.0	21.0	21.0
3	21.5	21.5	21.8	21.8	21.5	21.5
4	21.0	21.0	21.0	21.0	21.0	21.0
5	20.8	20.8	21.0	21.0	20.5	20.5
6	21.2	21.2	21.5	21.5	20.8	20.8
7	21.0	21.0	21.0	21.0	21.0	21.0
8	21.5	21.5	22.0	22.0	22.0	22.0
9	22.5	22.5	22.5	22.5	23.0	23.0
Range	20.8-22.5	20.8-22.5	21.0-22.5	21.0-22.5	20.5-23.0	20.5-23.0

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

Batch #5	Mean Percent Survival	
	Hyalella azteca[1]	*Chironomus tentans*[2]
Control #5	78%	68%
ERP 03	80%	60%
KMB 04	78%	48%
KMB 05	80%	65%
STP 06	50%	68%
STP 07	68%	68%
SUS 07	45%	0%

[1] Control survival was unacceptable (i.e., < 80% survival). Therefore, this test failed.
[2] Control survival was unacceptable (i.e., < 70% survival). Therefore, this test failed.

ACUTE TOXICITY TESTS
WITH
HYALELLA AZTECA AND *CHIRONOMUS TENTANS*
ON SEDIMENTS FROM THE DULUTH/SUPERIOR HARBOR:
1994 Sampling Results - Batch # 6

Conducted by

Minnesota Pollution Control Agency
Monitoring and Assessment Section
520 Lafayette Road
St. Paul, Minnesota 55155-4194

April 1997

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INTRODUCTION

As part of a sediment assessment of hotspot areas in the Duluth/Superior Harbor, sediment toxicity tests were conducted to assess acute (survival) and chronic (growth) toxicity to benthic invertebrates. Acute effects were measured in separate 10-day toxicity tests to *Hyalella azteca* (*H. azteca*) and *Chironomus tentans* (*C. tentans*). Growth was measured at the end of the C. *tentans* test to assess chronic effects. Survival and growth endpoints were compared to organisms similarly exposed to a reference control sediment collected from West Bearskin Lake (Cook County, MN).

A total of 44 sediment samples were collected for toxicity testing. This report presents the results of three of these sediment samples.

SAMPLE COLLECTION AND HANDLING

On September 29, 1994 and October 4, 1994, Minnesota Pollution Control Agency (MPCA) staff collected the three sediments referred to in this report. The samples were collected from the harbor using a gravity corer. The samples were stored at 4°C at the Duluth MPCA office until they were transported to the MPCA Toxicology Laboratory in St. Paul, MN.

METHODS

Three sediment samples and a control sediment were subjected to the 10-day sediment toxicity test using the procedures described in U.S. EPA (1994). The test organisms (*H. azteca* and *C. tentans*) were exposed to sediment samples in a portable mini-flow system described in Benoit et al. (1993) and U.S. EPA (1994). The test apparatus consists of 300 mL, glass-beaker test chambers held in a glass box supplied with water from an acrylic plastic headbox. The beakers have two, 1.5 cm holes covered with stainless steel mesh, to allow for water exchange while containing the test organisms. The headbox has a pipette tip drain calibrated to deliver water at an average rate of 32.5 mL/min. The glass box is fitted with a self-starting siphon to provide exchange of overlying water.

The *H. azteca* used for this test were 1 to 3 mm long, and the *C. tentans* were approximately 14 days old. These organisms were supplied by Environmental Consulting and Testing (Superior, WI) prior to the test set up.

On December 6, 1994, three samples (ERP 01, ERP 02, and STP 03) and the control sediment were separately homogenized by hand, and 100 mL of each sediment was placed in a test beaker (Batch #6). Approximately 100 mL of aerated, artesian well water was added to each beaker, and the sediments were allowed to settle for approximately two hours before the organisms were added. For each sediment, nine *H. azteca* were placed in each of four beakers in a random fashion, and ten *C. tentans* were placed randomly in another four beakers. An insufficient number of *H. azteca* organisms were received from the supplier to seed each beaker with ten organisms.

The organisms were exposed to 16 hours of light and eight hours of darkness for the duration of the ten-day test. Each day, two liters of aerated water from the artesian well at Stroh Brewery in St. Paul, MN were exchanged in each test chamber. On weekdays, 1-L was exchanged in the morning and 1-L in the afternoon. On weekends, the two liters were passed through the chambers all at once. Water quality measurements (i.e., pH, temperature, and dissolved oxygen) of the overlying water were taken in one beaker of each of the quadruplicate sets of each of the sediments. The results, along with daily observations involving the physical appearance of the sediments and organisms, were recorded in a laboratory notebook. This notebook is retained on file at the MPCA.

The test was terminated on December 16, 1994. The sediments were sieved through 40 mesh screens, and the sieved material was sorted for organisms. The organisms found were counted, and the number of alive and dead organisms were recorded. Organisms not found were recorded as missing and presumed dead. The *C. tentans* that survived were placed in aluminum weighing dishes, dried at approximately 100°C for at least four hours, desiccated to room temperature, and weighed.

Growth (weight) of the *C. tentans* and survival of both organisms were used as the endpoints for these tests. The survival data were analyzed using TOXSTAT (Gulley and WEST, Inc., 1994), a statistical software package obtained from the University of Wyoming. However, due to a quality assurance problem, the growth data were not analyzed.

A 96-hour, reference toxicant test with *H. azteca* in sodium chloride (NaCl) was run in conjunction with these toxicity tests to determine the acceptability of the *H. azteca* used. Four concentrations of NaCl solution (i.e., 10, 5, 2.5, and 1.25 g/L) and a control (aerated, artesian well water) were used in this test. Three replicates of five organisms each were set up per concentration.

RESULTS

Water Quality

Measurements of pH, dissolved oxygen, and temperature in the overlying water of the test beakers were made daily. These measurements are summarized below and in Tables 1, 2, and 3, respectively.

The range of pH values in the beakers containing *H. azteca* was 7.6 to 8.1 (Table 1). The water in the *C. tentans* beakers had a pH range of 7.5 to 7.9 (Table 1). The pH fluctuations during these tests were acceptable since they did not vary more than 50% within each treatment (U.S. EPA, 1994).

The dissolved oxygen concentration ranged from 3.6 to 7.4 mg/L in the *H. azteca* beakers and from 3.0 to 7.0 mg/L in the *C. tentans* beakers (Table 2). It should be noted that on Days 8 and 9, the dissolved oxygen concentration in the STP 3 sediment beaker containing *C. tentans* was less than 40% saturated, which is out of the acceptable test range for dissolved oxygen. The organisms continued to be fed throughout the test.

The temperature of the overlying water in each glass box was measured and ranged from 19.5°C to 21.5°C in the *H. azteca* beakers and from 19.5°C to 21.0°C in the *C. tentans* beakers (Table 3). The recommended temperature for these tests is 23 ± 1°C (U.S. EPA, 1994).

<u>Test Endpoints</u>

Survival Data

The mean percent survival of the test organisms is summarized below and in Table 4.

The mean percent survival of *H. azteca* in the control was 92% with a range of 89% to 100%. For the control sediment containing *C. tentans*, percent survival ranged from 70% to 90% with a mean of 85%. Survival for these controls was acceptable, and both tests passed.

Mean percent survival of *H. azteca* in the test sediments ranged from 58% in the ERP 02 sediment to 80% in the STP 03 sediment. Mean percent survival of *C. tentans* in the test sediments ranged from 62% in the STP 03 sample to 90% in the ERP 02 sample.

C. Tentans Growth Data

Although the dried *C. tentans* were weighed, the balance on which they were weighed was not calibrated with standard weights. Therefore, the data are suspect since the internal calibration of the balance may have drifted with time. Thus, no conclusions can be made regarding chronic toxicity (growth).

<u>Data Analysis</u>

All survival data were transformed using an arc sine-square root transformation. A one-tailed statistical test was used to test the alternative hypothesis that sample survival was less than control survival. For *H. azteca*, a nonparametric statistical test (i.e., Steel's Many-one Rank test) had to be used due to non-normal data. Only the survival of *H. azteca* in the ERP 02 sediment was significantly less than the control ($\alpha = 0.05$). For *C.* tentans, Dunnett's test was used to determine that none of the test sediments were toxic compared to the control sediment ($p = 0.05$). Results of the statistical analyses of these data are included in Appendix A.

<u>Reference Toxicant Test with *Hyalella azteca* in Sodium Chloride Solution</u>

The pH of the overlying water in the reference toxicant test ranged from 8.1 to 8.7. The dissolved oxygen ranged from 7.5 to 8.3 mg/L, and the temperature of the overlying water ranged from 20.0°C to 22.0°C. Survival of the organisms in the control was greater than 90% (i.e., 100%) which was acceptable.

The LC_{50} for this reference toxicant test was 4.45 g/L NaCl as determined by the Trimmed Spearman-Karber method and was within plus or minus two standard deviations of the running mean (Appendix B). The running mean for this test, which was 3.82 ± 1.14 g/L with a CV of 30%, was based on the previous five acceptable reference toxicant tests performed by this laboratory.

SUMMARY

Survival of *H. azteca* in the control sediment was acceptable (i.e., greater than 80%). Survival of the *H. azteca* in the reference toxicant test was also acceptable (i.e., greater than 90%). Survival of the *H. azteca* in the ERP 02 sediment was significantly less than the corresponding control survival ($\alpha = 0.05$).

Control survival was acceptable in the *C. tentans* test (i.e., greater than 70%), and there was no statistically significant difference between survival of the *C. tentans* in any of the test sediments with the control sediment.

REFERENCES

Benoit, D.A., G. Phipps, and G.T. Ankley. 1993. A sediment testing intermittent renewal system for the automated renewal of overlying water in toxicity tests with contaminated sediments. Water Research 27:1403-1412.

Gulley, D.D. and WEST, Inc. 1994. TOXSTAT 3.4. WEST, Inc., Cheyenne, WY.

U.S. EPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. EPA/600/R-94/024.

TABLE 1. Daily Overlying Water pH Measurements

Day	Control #6 *C. tentans*	Control #6 *H. azteca*	ERP 01 *C. tentans*	ERP 01 *H. azteca*	ERP 02 *C. tentans*	ERP 02 *H. azteca*	STP 03 *C. tentans*	STP 03 *H. azteca*
0*								
1*								
2	7.5	7.8	7.6	7.6	7.8	7.9	7.8	7.8
3	7.5	8.0	7.7	7.7	7.8	8.1	7.8	7.9
4	7.6	7.7	7.7	7.8	7.8	7.9	7.6	7.7
5	7.6	7.8	7.7	7.9	7.8	7.9	7.9	7.8
6	7.7	7.7	7.7	7.7	7.8	8.0	7.7	7.7
7	7.6	7.8	7.7	7.8	7.8	7.9	7.7	7.8
8	7.5	7.6	7.7	7.8	7.8	7.9	7.6	7.7
9	7.7	7.8	7.7	7.8	7.9	8.1	7.7	7.8
Range	7.5-7.7	7.6-8.0	7.6-7.7	7.6-7.9	7.8-7.9	7.9-8.1	7.6-7.9	7.7-7.9

***** Both of the pH meters were inoperable. Therefore, no measurements could be taken.

TABLE 2. Daily Overlying Water Dissolved Oxygen Concentrations (mg/L)

	Control #6		ERP 01		ERP 02		STP 03	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	6.2	6.3	6.4	6.7	7.0	7.4	6.8	6.8
1	6.5	6.4	6.4	6.5	6.8	6.4	6.2	6.6
2	5.9	6.3	5.5	6.1	5.9	6.7	5.9	6.6
3	5.3	6.1	5.5	6.2	5.0	6.3	4.9	6.0
4	4.1	5.8	3.9	6.0	4.6	5.5	4.2	5.2
5	5.2	5.5	5.1	5.8	4.5	5.5	4.4	5.4
6	5.9	6.0	5.1	6.1	4.9	6.0	4.9	5.5
7	4.6	5.0	4.8	5.8	4.6	5.2	3.9	4.2
8	4.6	4.8	4.8	5.0	4.3	4.9	3.0	3.6
9	4.2	5.3	4.6	5.2	4.3	5.1	3.2	4.3
Range	4.1-6.5	4.8-6.4	3.9-6.4	5.0-6.7	4.3-7.0	4.9-7.4	3.0-6.8	3.6-6.8

TABLE 3. Daily Overlying Water Temperatures (Degrees Celsius)

	Control #6		ERP 01		ERP 02		STP 03	
Day	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*	*C. tentans*	*H. azteca*
0	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
1	20.4	20.4	20.6	20.6	20.4	20.4	21.0	21.0
2	20.0	20.0	20.5	20.5	20.2	20.2	21.0	21.0
3	20.0	20.0	20.5	20.5	20.0	20.0	19.5	19.5
4	20.5	20.5	20.5	20.5	20.5	20.5	21.0	21.5
5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
6	20.2	20.2	20.5	20.5	20.5	20.5	21.0	21.0
7	20.2	20.2	20.5	20.5	20.2	20.2	21.0	21.0
8	20.0	20.0	20.5	20.5	20.0	20.0	21.0	21.0
9	20.2	20.2	20.8	20.8	20.4	20.4	21.0	21.0
Range	19.5-20.5	19.5-20.5	19.5-20.8	19.5-20.8	19.5-20.5	19.5-20.5	19.5-21.0	19.5-21.5

TABLE 4. Mean Percent Survival of *Hyalella azteca* and *Chironomus tentans*

	Mean Percent Survival	
Batch #6	***Hyalella azteca***	***Chironomus tentans***
Control #6	92%	85%
ERP 01	67%	78%
ERP 02	58%*	90%
STP 03	80%	62%

*Significantly less survival than the control, $\alpha = 0.05$.

APPENDIX A

TOXSTAT Analysis

94MUDPUPPY RUN #6 HYALELLA 12/6/94
4
4
4
4
4

CONTROL
0.89
1.00
0.89
0.89

ERP 1
0.11
0.89
0.89
0.78

ERP 2
0.56
0.44
0.67
0.67

STP 3
0.78
0.89
0.67
0.89

TITLE: 94MUDPUPPY RUN #6 HYALELLA 12/6/94
FILE: S:\MA\CHUBBAR\TSD\94MUD\94MPR6H.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 4

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.8900	1.2327
1	CONTROL	2	1.0000	1.4034
1	CONTROL	3	0.8900	1.2327
1	CONTROL	4	0.8900	1.2327
2	ERP 1	1	0.1100	0.3381
2	ERP 1	2	0.8900	1.2327
2	ERP 1	3	0.8900	1.2327
2	ERP 1	4	0.7800	1.0826
3	ERP 2	1	0.5600	0.8455
3	ERP 2	2	0.4400	0.7253
3	ERP 2	3	0.6700	0.9589
3	ERP 2	4	0.6700	0.9589
4	STP 3	1	0.7800	1.0826
4	STP 3	2	0.8900	1.2327
4	STP 3	3	0.6700	0.9589
4	STP 3	4	0.8900	1.2327

```
94MUDPUPPY RUN #6 HYALELLA 12/6/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR6H.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
----------------------------------------------------------------------

D =    0.662

W =    0.826

Critical W (P = 0.05) (n = 16) = 0.887
Critical W (P = 0.01) (n = 16) = 0.844
----------------------------------------------------------------------

Data FAIL normality test. Try another transformation.

Warning -  The first three homogeneity tests are sensitive to non-
normal
           data and should not be performed.


94MUDPUPPY RUN #6 HYALELLA 12/6/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR6H.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

----------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    9.11

----------------------------------------------------------------------
Table Chi-square value =   11.34  (alpha = 0.01, df =   3)
Table Chi-square value =    7.81  (alpha = 0.05, df =   3)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

94MUDPUPPY RUN #6 HYALELLA 12/6/94
File: S:\MA\CHUBBAR\TSD\94MUD\94MPR6H.DAT
Transform: ARC SINE(SQUARE ROOT(Y))

STEEL'S MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	CONTROL	1.275				
2	ERP 1	0.972	13.00	10.00	4.00	
3	ERP 2	0.872	10.00	10.00	4.00	*
4	STP 3	1.127	13.00	10.00	4.00	

Critical values use k = 3, are 1 tailed, and alpha = 0.05

94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
4
4
4
4
4

CONTROL
0.9
0.9
0.7
0.9

ERP 1
1.0
0.8
0.7
0.6

ERP 2
1.0
0.8
0.9
0.9

STP 3
0.8
0.5
0.7
0.5

TITLE: 94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
FILE: 94MPR6C.DAT
TRANSFORM: ARC SINE(SQUARE ROOT(Y)) NUMBER OF GROUPS: 4

GRP	IDENTIFICATION	REP	VALUE	TRANS VALUE
1	CONTROL	1	0.9000	1.2490
1	CONTROL	2	0.9000	1.2490
1	CONTROL	3	0.7000	0.9912
1	CONTROL	4	0.9000	1.2490
2	ERP 1	1	1.0000	1.4120
2	ERP 1	2	0.8000	1.1071
2	ERP 1	3	0.7000	0.9912
2	ERP 1	4	0.6000	0.8861
3	ERP 2	1	1.0000	1.4120
3	ERP 2	2	0.8000	1.1071
3	ERP 2	3	0.9000	1.2490
3	ERP 2	4	0.9000	1.2490
4	STP 3	1	0.8000	1.1071
4	STP 3	2	0.5000	0.7854
4	STP 3	3	0.7000	0.9912
4	STP 3	4	0.5000	0.7854

```
94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

Shapiro - Wilk's test for normality
----------------------------------------------------------------------

D =    0.328

W =    0.953

Critical W (P = 0.05) (n = 16) = 0.887
Critical W (P = 0.01) (n = 16) = 0.844
----------------------------------------------------------------------

Data PASS normality test at P=0.01 level. Continue analysis.


94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT       Transform: ARC SINE(SQUARE ROOT(Y))

----------------------------------------------------------------------
Bartlett's test for homogeneity of variance
Calculated B1 statistic =    1.30

----------------------------------------------------------------------
Table Chi-square value =   11.34  (alpha = 0.01, df =   3)
Table Chi-square value =    7.81  (alpha = 0.05, df =   3)

Data PASS B1 homogeneity test at 0.01 level. Continue analysis.
```

94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

GRP	IDENTIFICATION	N	MIN	MAX	MEAN
1	CONTROL	4	0.991	1.249	1.185
2	ERP 1	4	0.886	1.412	1.099
3	ERP 2	4	1.107	1.412	1.254
4	STP 3	4	0.785	1.107	0.917

94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

GRP	IDENTIFICATION	VARIANCE	SD	SEM	C.V. %
1	CONTROL	0.017	0.129	0.064	10.89
2	ERP 1	0.052	0.227	0.114	20.68
3	ERP 2	0.016	0.125	0.062	9.93
4	STP 3	0.025	0.159	0.080	17.39

94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT Transform: ARC SINE(SQUARE ROOT(Y))

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	3	0.254	0.085	3.104
Within (Error)	12	0.328	0.027	
Total	15	0.582		

Critical F value = 3.49 (0.05,3,12)
Since F < Critical F FAIL TO REJECT Ho: All equal

94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	CONTROL	1.185	0.850		
2	ERP 1	1.099	0.775	0.731	
3	ERP 2	1.254	0.900	-0.597	
4	STP 3	0.917	0.625	2.287	

Dunnett table value = 2.29   (1 Tailed Value, P=0.05, df=12,3)

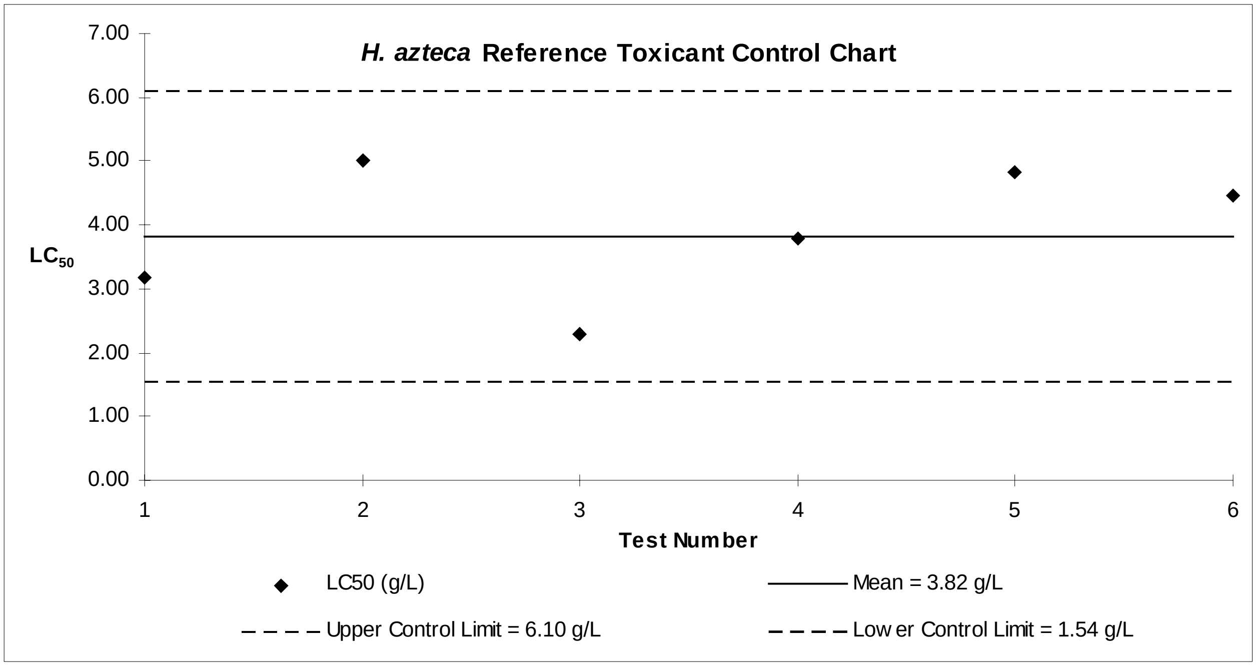
94 MUDPUPPY RUN #6 CHIRONOMIDS 12/6/94
File: 94MPR6C.DAT   Transform: ARC SINE(SQUARE ROOT(Y))

DUNNETT'S TEST - TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	CONTROL	4			
2	ERP 1	4	0.228	26.8	0.075
3	ERP 2	4	0.228	26.8	-0.050
4	STP 3	4	0.228	26.8	0.225

APPENDIX B

Reference Toxicant Control Chart
for *Hyalella azteca*



H. azteca Reference Toxicant Control Chart
7.00
6.00
5.00
4.00
LC50
3.00
2.00
1.00
0.00
1
2
3
4
5
6
Test Number
LC50 (g/L)
Mean = 3.82 g/L
Upper Control Limit = 6.10 g/L
Low er Control Limit = 1.54 g/L

APPENDIX C

BENTHOLOGICAL COMMUNITY DATA

APPENDIX C

BENTHIC MACROINVERTEBRATE DATA FILES

The below data files contain the benthological abundance and taxa richness data. Due to the large size of these files, each site file is split into an oligochaete and insect data file. All files are in Lotus 1-2-3, version 2.3, and are provided on the computer disk at the back of this report. Since all of the files are compressed, access the Readme.txt file first for directions on how to read the files.

DMIR Sites

dmirinse.wk1

dmirolig.wk1

ERP Sites

erpinsec.wk1
erpoligo.wk1

HOB Sites

hobinse1.wk1
hobinse2.wk1
hobolig1.wk1
hobolig2.wk1

KMB Sites

kmbinsec.wk1
kmboligo.wk1

MLH Sites

mlhinsec.wk1
mlholigo.wk1

MNS Sites

mnsinsec.wk1
mnsoligo.wk1

STP Sites

stpinsec.wk1
stpoligo.wk1

SUS Sites

susinsec.wk1
susoligo.wk1

WLS Sites

wlsinse1.wk1
wlsinse2.wk1
wlsolig1.wk1
wlsolig2.wk1