WORK PLAN
FOR THE REMEDIAL DESIGN
OF OPERABLE UNITS 2, 3, 4 AND 5
LOWER FOX RIVER AND GREEN BAY SITE
BROWN, OUTAGAMIE, AND WINNEBAGO COUNTIES, WISCONSIN

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For Submittal to:

Wisconsin Department of Natural Resources

U.S. Environmental Protection Agency

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ACRONYMS

°F	degree Fahrenheit
Anchor	Anchor Environmental, LLC
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirements
ASCII	American Standard Code for Information Interchange
BBLES	BB&L Environmental Services
BMP	best management practice
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
cm	centimeter
cm/s	centimeter per second
COC	contaminant of concern
CQAPP	construction quality assurance project plan
CST	column settling test
cy	cubic yard
DEA	Detailed Evaluation of Alternatives
DMU	dredge management unit
DRET	Dredging Elutriate Test
EDD	Electronic Data Deliverable
ESD	Explanation of Significant Difference
FGDC	Federal Geographic Data Committee
FIELDS	Field Environmental Decision Support
Fort James	Fort James Operating Company, Inc.
fps	feet per second
FRDB	Fox River Database
FRG	Fox River Group
FS	feasibility study
g/cm^3	grams per cubic centimeter
GAS/SAIC	Graef, Anhalt, Schloemer & Associates/Science Applications International Corporation
GBMBS	Green Bay Mass Balance Study
GIS	Geographic Information System
GLNPO	Great Lakes National Program Office
HASP	Health and Safety Plan
IDW	inverse-distance-weighted
IGLD	International Great Lakes Datum
kg	kilogram
lb	pound
LTA	long-term average
LTI	Limno-Tech, Inc.
MET	Modified Elutriate Test

mg/L	milligram per liter
MNR	Monitored Natural Recovery
NCP	National Contingency Plan
NCR	NCR Corporation
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NTU	Nephelometric turbidity unit
OMMP	Operations, Maintenance, and Monitoring Plan
OSI	Ocean Surveys, Inc.
OU	Operable Unit
PCA	Project Cooperation Agreement
PCB	polychlorinated biphenyl
pcf	pounds per cubic foot
PCLT	pancake column leach test
ppm	part per million
psf	pounds per square foot
psi	pounds per square inch
QAPP	Quality Assurance Project Plan
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RI	remedial investigation
RM	river mile
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SAV	submerged aquatic vegetation
Shaw	Shaw Environmental & Infrastructure, Inc.
SMU	sediment management unit
SOW	Statement of Work
SPT	Standard Penetration Test
SRD	sediment redevelopment
STL	Severn Trent Laboratories, Inc.
SWAC	surface-weighted average concentration
TBD	to be determined
TCLT	thin-layer column leach test
TIN	triangulated irregular network
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TSS	total suspended solids
µg/kg	microgram/kilogram
µg/L	microgram/liter
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

UU	unconsolidated undrained
VST	vane shear test
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollution Discharge Elimination System
WRDA	Water Resources Development Act

1 INTRODUCTION

This Remedial Design (RD) Work Plan presents the design phases, tasks, and sequencing necessary to complete remedial design in Operable Units (OU) 2, 3, 4 and 5 of the Lower Fox River and Green Bay Site (Site; Figure 1-1). The requirements for RD are set forth in the Administrative Order on Consent (AOC) and associated Statement of Work (SOW) for OUs 2–5 (USEPA, 2004), executed in March 2004 by Fort James Operating Company, Inc. (Fort James) and NCR Corporation (NCR) (collectively the "Respondents") in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency Region (USEPA)(collectively the "Response Agencies"). This RD Work Plan addresses only OUs 2–5. The remedial design of OU 1 is being addressed under a separate agreement between WDNR, USEPA, and the WTM1 Company.

1.1 Project Background

The PCB cleanup remedy for the Lower Fox River is set forth in Records of Decision (ROD) for OUs 2–5 signed by WDNR and USEPA in December 2002 and June 2003. As set forth in the AOC, the Respondents have agreed to design the remedy for OUs 2, 3, 4, and 5 consistent with the ROD requirements (i.e., dredging and transport to an upland disposal facility), and where appropriate to explore practicable design alternatives. The RD will address the timing and sequencing of the remedial action to account for the multifaceted and multi-year components of the remedy. The Response Agencies and Respondents will collaboratively seek to resolve key technical and implementation issues through the timely use of Work Groups and other communications. The Respondents and Response Agencies will also give appropriate consideration to and incorporate into the RD process the contingent remedy provisions of the ROD, and such other work as proposed and/or conducted by Respondent under the AOC.

1.2 General Description of ROD Remedial Actions

1.2.1 Operable Unit 2 (Excluding Deposit DD)

The selected remedy for OU 2 is Monitored Natural Recovery (MNR). An institutional control plan and a long-term monitoring plan for PCB and possibly mercury levels in water, sediment, invertebrates, fish and birds will be developed during the remedial design. Institutional controls may include access restrictions, land use or water use restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas.

Plans for monitoring will be developed during remedial design and modified during and after the upstream construction in OU 1, as appropriate. The monitoring program will be developed to effectively measure achievement of and progress towards the Remedial Action Objectives (RAO) specified in the RODs.

1.2.2 Operable Units 3 and 4 (Including OU 2 Deposit DD)

The selected remedy for OUs 3 and 4 includes the removal of sediment with PCB concentrations greater than the 1 part-per-million (ppm) remedial action level (RAL) using dredging methods that minimize environmental impacts, followed by dewatering and off-site disposal of the sediment. This remedy includes the following:

- **Site Mobilization and Preparation**. The staging area(s) for these OUs will be determined during the remedial design stage. Site preparation at the staging area(s) will include design and baseline site characterization, securing the onshore property area for equipment staging, and constructing the necessary onshore facilities for sediment management and transportation.
- **Sediment Removal**. Sediment removal will be conducted using an appropriate dredge or other suitable sediment removal equipment.
- **Sediment Dewatering**. Sediment that is removed may require dewatering to facilitate transport and/or disposal.
- **Sediment Disposal**. Sediment disposal includes the transportation of the sediment to a dedicated engineered landfill, consistent with Wisconsin Administrative Code NR 500 regulations.
- **Water Treatment**. Unless other arrangements are made, water treatment will achieve performance standards set forth in the RODs, and may consist of flocculation, clarification, sand filtration, and treatment through activated carbon filters.
- **Demobilization and Site Restoration**. Demobilization and site restoration will involve removing equipment from the staging and work areas and restoring the site to, at a minimum, its original condition before construction of the staging area commenced.
- **Institutional Controls and Monitoring**. Plans for monitoring of various media (e.g., water, tissue, and sediment) to determine the effectiveness of the overall remedy will be developed during the remedial design. Baseline monitoring may include pre-remedial construction sampling of water, sediment, and biological tissue. Monitoring during implementation will include surface water sampling and may include air sampling. Plans for monitoring during and after construction will be developed during the remedial design and modified during and after construction, as appropriate. A long-term monitoring and institutional control plan will be

developed as part of the remedial design. Institutional controls may include access restrictions, land use or water use restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas.

- **Achievement of Remedial Action Level Objectives**. As discussed above, the selected remedy for OUs 3 and 4 includes dredging of sediment with PCB concentrations greater than the 1-ppm RAL. After the remedial action is completed, the surface-weighted average concentration (SWAC) will be compared with the RAOs of 0.26 ppm for OU 3 and 0.25 ppm for OU 4. Sampling will be conducted to determine if the RAL or SWAC have been achieved. The SWAC will be computed following completion of the dredging with surface sediment samples collected from 0 to 10 centimeters (cm) below mudline. The SWAC will be calculated across the entire submerged area of each OU, including dredged, non-dredged, and if applicable, capped areas to represent area-wide exposures to humans or wildlife. Surface sediment samples will also be collected as part of the field program proposed herein to help estimate the post-remediation SWAC under different remediation scenarios.

1.2.3 Operable Unit 5

The selected remedy for OU 5 includes MNR with institutional controls and limited dredging. This remedy includes the following:

- **Additional Sampling / Dredging**. Additional sampling near the mouth of the Lower Fox River will be conducted to identify sediments with PCB concentrations greater than 1 ppm. PCB-contaminated sediments immediately adjacent to the River mouth with concentrations greater than 1 ppm will be dredged as an extension of the OU 4 removal.
- **Institutional Controls and Monitoring**. An institutional control plan and a long-term monitoring plan for PCB and possibly mercury levels in water, sediment, invertebrates, fish and birds will be developed during the remedial design. Institutional controls may include access restrictions, land use or water use restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas. Plans for monitoring will be developed during the RD and modified during and after the upstream construction in OUs 3 and 4, as appropriate. The monitoring program will be developed to effectively measure achievement of and progress towards RAOs.

1.2.4 Contingent Remedy – In Situ Capping

Capping of certain areas and other alternative remedial measures may be proposed by the Respondents during RD and will be given consideration by the Response Agencies, consistent with the requirements of the ROD for selection of the contingent remedy. The specific areas where caps could be placed or where other remedial measures could be implemented will be evaluated during RD.

1.3 Applicable or Relevant and Appropriate Requirements

Applicable or Relevant and Appropriate Requirements (ARARs) for the remedial design are set forth in the RODs for OUs 2–5. The remedial design will be consistent with the ARARs listed in the RODs.

1.4 Remedial Design Approach

This RD Work Plan is intended to achieve an expedited, cost-effective RD that builds on prior work, is protective of human health and the environment, is consistent with the National Contingency Plan, and complies with the RODs. The RD will be a collaborative and cooperative process between the Response Agencies and Respondents. The parties will meet and confer on a regular basis and seek to anticipate and resolve key issues in advance of document completion.

Remediation work in OU 1 will likely precede remediation efforts in OUs 2–5. Also, it is possible that pilot projects may be implemented in one or more OUs (including OU 1) before certain components of the remedy are implemented on site-wide, full-scale basis. The RD process will consider, and make adjustments in the RD work based on information and experience from remedial efforts that have been completed to date (e.g., Sediment Management Unit (SMU) 56/57 Demonstration Project), as well as the work, tasks, projects and investigations that will be undertaken as the RD is being developed. The RD process will have the flexibility to adapt as appropriate to what is learned from those efforts. To this end, an Adaptive Management Plan will be developed during the RD outlining how adaptive management principles will be applied during and after construction of the remedy.

The RD will be a phased and iterative process. Proper sequencing of tasks will be important, and the RD will be conducted so pertinent information will be taken into account as it becomes available. The sequence of data collection is also important. By phasing certain data collection components, preliminary evaluations may be made that will obviate the need for further data collection or evaluations upon approval by the Response Agencies.

As set forth in the AOC/SOW (USEPA, 2004), the RD for OUs 2–5 will consist of the following tasks:

I. Remedial design planning;

II. Summer 2004 sampling and analysis;

III. Initial remedial design activities;

IV. Preparation of Basis of Design report,

V. Pilot projects and supplemental investigations; and

VI. Preparation of remedial design documents.

This RD Work Plan contains the results of the initial remedial design planning. In developing this Work Plan, existing data available for OUs 2–5 were compiled into a suitable geographic information system (GIS) platform to provide a detailed assessment of the extent of contamination and physical characteristics of the river channel and side-slope areas, and location of candidate areas for active remediation or MNR, based on the RODs. This effort is focused on identifying data needed for summer 2004 sampling and analysis and initial remedial design activities. Additionally, information on future land use planning, including future dredging and channel de-authorization plans, and Water Resources Development Act (WRDA) feasibility study plans and activities, has been compiled.

The review and analysis of existing data is presented in Section 2 of this RD Work Plan, which forms the basis for development of this RD Work Plan, while subsequent sections discuss how each component of the RD will be addressed, including phases, tasks and sequencing necessary to complete the RD. This RD Work Plan also presents a project schedule for major activities and submissions (Section 5). The schedule may require amendment if new information is discovered that was not anticipated at the time the Work Plan was developed, or if any changes are made in design or management strategy. The overall management plan for completion of the RD is provided in Section 6 of this Work Plan, including documentation of responsibilities and authorities of the entities and key personnel involved in the RD.

2 REVIEW AND ANALYSIS OF EXISTING DATA

In developing this RD Work Plan, existing available data were compiled and summarized to provide an assessment of current information on the extent of contamination, existing sources of contamination, bathymetry and sub-bottom profiles of the river channel and side-slope areas, and the location of candidate areas for active remediation or MNR, based on the RODs. Preliminary assessments of dredging, transport, upland landfill disposal, and MNR elements of the selected remedy, along with concurrent assessments of the contingent capping remedy and alternative disposal sites, were performed to focus summer 2004 sampling and analysis and initial remedial design efforts. Available information on land use plans, including future dredging and channel de-authorization plans, and WRDA feasibility study plans and activities, were also integrated into this analysis. The review and analysis of existing data presented in the sections below focused on those sediment deposits in OUs 2 (Deposit DD), 3, 4, and possibly a portion of OU 5 that are identified in the RODs as requiring remedial action.

2.1 Lower Fox River Database for OUs 2, 3, 4 and 5

A large set of information has been collected and reported for the environmental management of the Fox River. Most of the available information has previously been compiled by WDNR into the Fox River Database (FRDB). This information is also available in the FoxView database (version 7; LTI, 2003), which includes additional information collected as described below by the U.S. Geological Survey (USGS), the Fox River Group (FRG), and others. In addition, a GIS and analytical database is under development by the Respondents to maximize the usefulness of this historical data for the remedial design. Database development activities to facilitate the ongoing evaluation and remediation activities for the Lower Fox River project include the following:

- Relational database evaluation and augmentation;
- Spatial data evaluation and consolidation; and
- Website and document sharing portal development.

The FoxView database (version 7) has been downloaded and evaluated from an on-going use perspective. To facilitate the use of this volume of critical data with the associated spatial data, latitude and longitude data (currently housed in degree, minute, decimal seconds) has been converted to a standard coordinate system (decimal degrees and Wisconsin Transverse

Mercator) and added to the database in a new table in order to preserve the existing data, rather than replace it.

A summary of the data layers by data type is provided in Table 2-1. The largest task associated with the spatial data component of the database development project was the consolidation of spatial data and the creation of Federal Geographic Data Committee (FGDC)-compliant metadata. Additionally, regional data such as roads, municipal boundaries, and regional hydrography, have been downloaded from the U.S. Census Bureau TIGER data sets for up-to-date and attributed (annotated) datasets. These activities limit the number of files required for use in evaluation (and transfer) ensuring that when spatial data are used, the end-user is fully aware of what he is using and the purpose of that dataset. The ability of a GIS to query and filter makes large datasets simple to use and manage. A goal of the consolidation effort is to create an Internet Map Service allowing all authorized project users to easily view and query spatial and analytical data via the Internet.

For the duration of the Lower Fox River Remedial Design Project set forth in the AOC, data will be submitted to WDNR in a format compatible with WDNR's database. The WDNR database uses a standard file format for receiving analytical data. Each file will be submitted in standard American Standard Code for Information Interchange (ASCII) format and consist of a variable number of records containing location, sample and result data. Electronic Data Deliverable (EDD) requirements as specified in the Appendix F of the accompanying Sampling and Analysis Plan (SAP) will be adhered to for all analytical data submittals (Shaw and Anchor, 2004a).

Spatial data will follow a project standard that facilitates the activities of the remedial design effort. The data will be managed by type (vector versus raster) and by OU, with the exception of regional data such as roads, municipalities, and the Fox River boundary, etc. At a minimum, however, spatial data will have a defined projection and metadata for all layers being used and potentially transferred to other team members.

Historical data collected in support of the Lower Fox River Remedial Investigation/Feasibility Study (RI/FS) and RODs were accessed via the internet at http://www.tecinfodex.com/frdb, which is a non-WDNR website maintained by WDNR's sub-consultant, TEC INFODEX. The data were returned in a flat file format and can be used for data display and analysis.

2.2 Physical, Hydraulic, and Geotechnical Conditions

The Lower Fox River is divided into five operable units:

- OU 1 is also known as Little Lake Butte des Morts. The Neenah and Menasha Dams control the pool elevation of Lake Winnebago and the discharge to the upstream end of OU 1 at river mile (RM) 39. Remedial design of OU 1 is being addressed under a separate SOW and Consent Order.
- OU 2 extends from the Appleton Locks at RM 31.9 to the Little Rapids Dam at RM 13.1. This unit contains the majority of locks and dams in the Lower Fox River system and the greatest elevation drop and gradient. Sediments have a very patchy distribution in this reach with extensive intervening bedrock exposures. This Work Plan only addresses Deposit DD for active remediation, while MNR is the selected remedy for the remainder of OU 2.
- OU 3 extends from the Little Rapids Dam to the De Pere Dam at RM 7.1. Soft sediment covers most of this unit. This unit contains a federal navigation channel that is not currently maintained by the U.S. Army Corps of Engineers (USACE).
- OU 4 extends from the De Pere Dam to the river mouth at Green Bay. This unit contains a federal navigation channel, a portion of which is currently maintained by the USACE (see Section 2.2.4). The area around OU 4 is highly urbanized, including the City of Green Bay.
- OU 5 begins at the river mouth, and includes the entire bay of Green Bay. The primary focus of this Work Plan is a relatively small deposit located immediately offshore of the Fox River mouth, which will be investigated further to characterize the extent of PCBs exceeding the 1-ppm RAL.

Specific soft sediment deposits have been mapped in OUs 2 and 3 (e.g., Deposit HH), and were evaluated as part of the RI/FS previously prepared for the Lower Fox River Site (Figure 2-1) (Retec, 2002b, 2002c). In contrast, soft sediment deposits are more widespread in OU 4, with the exception of relatively steep embankment areas. As a result, OU 4 is described in terms of SMUs rather than specific sedimentary deposits (Figure 2-1).

2.2.1 Geology and Hydrogeology

2.2.1.1 Geology

The Lower Fox River valley is underlain by Paleozoic bedrock primarily comprised of Ordovician limestone and dolomite of the Sinnipee Group (Galena, Platteville, and Decorah Formations). The modern geomorphology of the region has been heavily modified by glaciation. Unconsolidated Quaternary glacial deposits ranging from 50 to 200 feet thick cover the bedrock in the valley; these deposits consist primarily of silty clay and clay loam tills with associated sand and gravel outwash and lacustrine deposits of proglacial lakes. Superimposed on the glacial deposits are modern fluvial and alluvial deposits of the river and its floodplain (Krohelski and Brown, 1986).

2.2.1.2 Groundwater Hydrogeology

Three aquifer systems are present in the Lower Fox River valley and have been generally described by USGS (1992) as follows:

1. *Upper Aquifer (unconsolidated Quaternary deposits in hydraulic continuity with Ordovician Sinnipee).* The Ordovician dolomites typically yield only enough water for domestic supply wells and in many areas form an effective confining unit.

2. *St. Peter Aquifer (Ordovician sandstone).* The St. Peter sandstones yield abundant water but also contain significant amounts of naturally-occurring dissolved minerals. The St. Peter Aquifer has been used extensively as a water supply source for the Fox River Valley, resulting in a pronounced cone of depression and a corresponding drop in hydraulic head of 100 to 400 feet compared to its once-artesian, pre-development levels.

3. *Elk Mound Aquifer (Cambrian sandstone).* The Elk Mound Aquifer is separated from the St. Peter Aquifer by the St. Lawrence Formation, a silty dolomite. The hydraulic properties of the Elk Mound Aquifer are similar to those of the St. Peter Aquifer, and it also serves as a primary water supply source for the area (USGS, 1992).

A conceptual-level cross section of aquifer systems present in the Lower Fox River valley is provided on Figure 2-2.

2.2.1.3 Surface Water Hydrology

The Lower Fox River flows northeast for 39 miles from Lake Winnebago, the largest inland lake in Wisconsin, to Green Bay (Figure 2-1). The Fox River is the largest tributary to Green Bay, draining approximately 6,330 square miles with a mean annual discharge of 5,000 cubic feet per second (cfs) (USGS, 1998). From Lake Winnebago to Green Bay, the river drops 168 feet over a series of locks and dams, as described in Section 2.2.4.2.

The Lower Fox River flows across a relatively low permeability substrate comprised of Quaternary deposits of lacustrine clay, silt, and glacial till throughout much of its length. In addition, bedrock exposures of the Sinnipee dolomite crop out in the river bed in parts of OU 2, forming rapids, a narrow channel, and only localized accumulations of soft sediment.

Groundwater Discharge. Groundwater in the Upper Aquifer generally follows local topography and therefore flows toward the river. However, drawdown in the St. Peter Aquifer beneath the river valley induces downward flow from the Upper Aquifer to the St. Peter Aquifer and reduces the amount of discharge to the Lower Fox River and its tributaries (Figure 2-2). Groundwater discharge to the river is further limited by the relatively impermeable river bed formations, low gradients, high surface runoff from the glacial soils and therefore limited recharge of the Upper Aquifer (Conlon, 1998; USGS, 1998).

Seiche Events. Green Bay is subject to seiche events—short-term changes in water level elevation caused by northeasterly winds or barometric pressure differentials that cause water build up in the southern end of the bay. Seiche events can increase water levels near the mouth of the river by a few inches to a few feet when combined with storm conditions. This can cause a short-term reversal of flow direction in OU 4 and induce rapid mixing of bay and river waters (Smith et al., 1988).

Green Bay Water Level Elevations. The water level elevation in Green Bay is controlled by water levels in the Lake Michigan-Huron basin. The long-term average (LTA) elevation for the lake basin between 1918 and December 2003 is 578.94 feet International Great Lakes Datum (IGLD) 1985, as shown on the hydrograph on Figure 2-3. The historical low and high lake water levels since 1918 are 576.05 feet (March 1964) and 582.35 feet (October 1986), respectively (USACE, 2004b). Recent lake levels have been below LTA elevations, due to lower than average snowmelt runoff and several consecutive warm winters.

Rainfall-Runoff. Mean monthly air temperatures in Green Bay range from a low of 14.3 degrees Fahrenheit (˚F) in January to a high of 69.7˚F in July. Average monthly temperatures for December through March are below freezing. In a typical year, Green Bay receives 28.8 inches of total precipitation, including 48.5 inches of snow. The month of April generally exhibits the highest river flows, due to winter snow melt combined with spring rain. The late summer months of August and September generally exhibit the lowest flows (Retec, 2002c). Further information on Lower Fox River flows is provided in Section 2.2.6 – River Hydrodynamics.

2.2.2 Bathymetry and Water Depth

Bathymetric information for the Lower Fox River is available from a number of sources. Ocean Surveys, Inc. (OSI) performed a bathymetric survey of the Lower Fox River in June 1998 along transects approximately 300 feet apart in OUs 1, 3, and 4. However, the OSI surveys are not considered sufficient for design because coverage did not include certain inaccessible areas near dams and in nearshore shallow waters. In addition, it is unclear which type of equipment was used for the surveys and water elevations were not recorded at the time of the survey, making it difficult to accurately correlate mudline elevations to a vertical datum.

The USACE office in Kewaunee, Wisconsin, collects bathymetric data annually in the navigation channel in OU 4 and in Green Bay to support maintenance dredging operations. The surveys cover the area between the channel entry 12 miles out in Green Bay to the turning basin just below the De Pere Dam, although dredging no longer occurs between the De Pere Dam and Fort Howard turning basins.

The most recent bathymetric data which provides comprehensive coverage of the Lower Fox River was collected by USEPA's Field Environmental Decision Support (FIELDS) Program in 2002. These data, collected using a single-beam acoustic sounder with line spacings of approximately 100 feet, is the basis for the bathymetric maps presented in Figure 2-4.

The line spacing used in the OSI and FIELDS Program surveys are considered sufficient for navigational and site characterization purposes, but higher density measurements will be necessary for remedial design.

In order to provide bathymetry data sufficient for remedial design, Retec will perform additional surveys during Summer 2004. The 2004 bathymetric survey, which will be performed under a separate agreement with WDNR, will include the use of a multiple transducer, single-beam sweep system that can collect data over a 35-foot swath, ultimately resulting in a 3-foot by 5-foot data point grid. A higher resolution, multi-beam bathymetric survey may be conducted over features demonstrating high relief or extreme bed elevation change. This secondary bathymetric survey is dependent on the results of the single-beam survey (Retec et al., 2003a, 2003b).

Based on a review of the Retec 2004 bathymetric survey sampling and analysis plan (Retec SAP) (Retec et al., 2003b), the bathymetric survey data should be adequate to support remedial design and will replace the USEPA FIELDS data. It is possible that localized data gaps could be identified following merging by Retec of the bathymetric and adjacent upland topographic data.

The current understanding of the bathymetric features of the various OUs based on previous surveys is described below.

OU 2. As described in the ROD, the only portion of OU 2 that is being evaluated for active remediation is Deposit DD, which extends about 4,000 feet upstream from the Little Rapids Dam (WDNR and USEPA, 2003). The river in this downstream reach of OU 2 is about 500 to 1,000 feet wide. This is also the deepest part of the OU 2 pool, with water depths typically ranging from 10 to 15 feet.

OU 3. OU 3 includes the 7-mile-long pool between the Little Rapids and De Pere Dams. The river is widest, over 2,000 feet, at its southern end, tapering to less than 1,000 feet at the narrows above the De Pere Dam. The main channel depth is greater than 6 feet in most places, deepening to 15 to 18 feet above the De Pere Dam. Relatively shallow (several feet of water) shoaling areas are located along both banks in the southern part of OU 3, including a particularly broad shallow area on the east bank near RM 12.2 covering approximately 45 acres near Lost Dauphin State Park (NOAA, 1992).

OU 4. The river is broad and shallow at the upper end of OU 4 between the De Pere Dam and the Fort Howard turning basin. The river width in this area varies from about 1,000 to 3,000 feet. Outside the narrow navigation channel, which is no longer maintained, much of this width is occupied by shallow benches along both banks with water depths of 1 to 5 feet. Downstream of the Fort Howard turning basin, the channel is routinely dredged to maintain a federally authorized navigation depth of 24 feet, and the river narrows to between 500 and 700 feet throughout much of this downstream section. The 300-foot wide navigation channel occupies much of the width the river, creating more of an engineered channel morphology with steeper side slopes.

The normal pool elevations maintained in the OUs are as follows:

Pool	Operable Unit	River Mile	Normal Pool Elevation (feet IGLD 85)	Lift (feet)
Green Bay	OU 4/5	0.0	577.5	
De Pere Dam	OU 3	7.1	587.4	9.9
Little Rapids Dam	OU 2	13.1	593.5	6.1

It should be noted that the water elevation in OU 4 is not controlled by any dams or locks and is influenced by the water elevation in Green Bay, which in turn is influenced by the fluctuation of Lake Michigan-Huron (Figure 2-3).

2.2.3 Sediment Thickness and Stratigraphy

Numerous studies have been conducted since 1989 to characterize the physical properties of the bed sediments in the Lower Fox River. In 1999, during the conduct of the RI/FS, WDNR compiled data from eight of these previous investigations and developed a methodology for interpolating between the discrete data locations to generate three-dimensional GIS-based maps (WDNR, 1999b). Table 2-3 lists the data sources used by WDNR to generate their GIS maps.

Since the development of that combined database, other data sets have been published in subsequent reports including the RI (Retec 2002c), data collected on behalf of the FRG in 2000 and 2001 (LTI, 2001, 2002a), and a report prepared by the USGS, Johnson Company, and Sea Engineering (USGS et al., 2004). The following sections present a summary of the data collected during the various investigations.

2.2.3.1 Sediment Stratigraphy

The Lower Fox River RI (Retec, 2002c) identified the following three general sediment layers as observed in sediment cores collected within the river:

Layer 1 “The surface layer is primarily fine-grained, unconsolidated sediment with a high organic content. Sediments in this layer are fairly recent in age and may be susceptible to resuspension if located in areas of peak flow velocity and bed shear stress conditions.”

Layer 2 “This subsurface layer consists of fine-grained sediments with slightly more sand and gravel along with shell and wood debris. Based on field observations, these sediments are usually more compact, with less water content than the surface layer and would likely require somewhat higher flow velocities/shear stresses to achieve resuspension.”

Layer 3 “This basal layer is the native glacial material that underlies the river. This material typically consists of red-orange, stiff, damp to dry, silty clay, similar to the glacial till in the region.”

2.2.3.2 Sediment Thickness

Distinct deposits of unconsolidated sediment have been identified throughout the Lower Fox River (WDNR, 1989/90; WDNR, 1995; and GAS/SAIC, 1996). Sediment thickness measurements were collected by a physical probing method, i.e., by pushing a graduated 2.5-inch diameter aluminum sounding pole through the soft sediment and measuring the depth to refusal (presumably native glacial material). Figure 2-5 presents a color contour map of sediment thickness in OU 3 and OU 4 (and Deposit DD in OU 2) (WDNR, 1999b).

OU 2 (Deposit DD) and OU 3. Areas located in portions of the river where stream flow velocities decrease as a result of natural and man-made channel features (e.g., dams) have experienced a net depositional gain of sediment over time. The majority of these areas are located upstream of the dams (upstream of De Pere Dam in OU 3 and upstream of the Little Rapids Dam in OU 2) or in areas where the width of the river increases. The total thickness of soft sediment behind these dams ranges from 4 to 7.5 feet. The soft sediment thickness over the majority of Deposit EE, which covers much of OU 3, ranges from 3 to 4 feet.

OU 4. Downstream of the De Pere Dam in OU 4, much of the river has also experienced net depositional gain. This widespread deposition is likely due to reduced river gradient and flow reversals caused by seiches (Section 2.2.6) as well as cessation of historical channel maintenance upstream of the Fort Howard turning basin. Soft sediment thickness between the De Pere Dam and SMU 38 (the upper 3 miles of OU 4) is estimated to be up to 3.3 feet. Downstream of SMU 38, much of river bottom is covered by soft sediment in excess of 3.3 feet, ranging up to 12 to 19 feet in the vicinity of the Fort Howard turning basin (Retec, 2002c). Downstream of the turning basin, the federal navigation channel is routinely maintained by dredging soft sediments (Section 2.2.4.3).

2.2.3.3 Grain Size

In general, the sediment bed of OU 3 and OU 4 (and Deposit DD in OU 2) in the Lower Fox River is comprised of mainly sand- and silt-sized particles. Sand and silt account for approximately 82 percent, on average, of the sediment by weight. Clay-sized particles account for nearly all of the remaining 18 percent, with a very small fraction (less than 0.3 percent on average) of the particles in the gravel-sized or larger range. On average, sediments in this area contain approximately 62 percent fine-grained (silt- and clay-sized) particles.

Table 2-4 presents a summary of grain size data compiled by WDNR (1999b), along with subsequent data collected and presented in the RI Report (Retec, 2002c) and by the USGS et al. (2004). The grain size data are useful in evaluations of dredging and residual management technologies as may be applied to the site, and also suggest that solids separation of relatively coarse-grained materials (e.g., sand-sized particles) may provide cost efficiencies for certain disposal options (see below).

2.2.3.4 Index Parameters and Other Physical Properties

Atterberg Limits. Atterberg Limit data, collected in 1998 during WDNR and FRG sampling activities, are presented in Table 2-5. These data showed high liquid and plastic limits, with the majority of the samples classified as high compressibility silts (MH) while one sample was classified as a highly plastic clay (CH), as defined by the Unified Soil Classification System.

TOC. Total organic carbon (TOC) content was measured in numerous sediment samples collected from OU 3 and OU 4, as presented in WDNR (1999b) and the RI (Retec, 2002c). A summary of these data is presented in Table 2-6 and the WDNR (1999b) data is presented graphically on Figure 2-6. The average TOC content in samples of soft fine-grained sediments (Layer 1) collected from the Lower Fox River are summarized below:

Data Source	OU 2 (Deposit DD only)	OU 3	OU 4
WDNR (1999b)	4.4%	6.0%	4.2%
RI (Retec, 2002c)	3.9%	5.7%	4.5%

On average, the TOC content in recent sediments collected from Deposit DD, OU 3, and OU 4 was approximately 4.5 percent.

Percent Solids. Percent solids by weight of soft (Layer 1) sediment samples collected from OU 3, OU 4, and OU 2 (Deposit DD) are summarized in the RI (Retec, 2002c) and in Table 2-6. On average, soft (Layer 1) sediments contain approximately 40 percent solids by weight, with a range from 13 to 88 percent solids. In OU 4, surficial sediments collected within 2 feet of the mudline had somewhat lower percent solids (36 percent) compared to deeper subsurface sediments collected at depths of 2 to 8 feet below the mudline (46 percent).

Density. Dry and wet bulk density, as summarized in WDNR (1999b) and the RI (Retec, 2002c), are presented in Table 2-6. The bulk densities reported by WDNR (1999b) are presented in Figure 2-7. According to measurements summarized in Retec (2002c), the average wet bulk density and dry bulk density of soft (Layer 1) sediments in the study area are 73 pounds per cubic foot (pcf) (1.27 grams per cubic centimeter, g/cm^3) and 32 pcf (0.52 g/cm^3), respectively. A significantly lower wet bulk density (45 pcf, or 0.72 g/cm^3) was reported by WDNR (1999b). Test results presented by the USGS et al. (2004) (average wet and dry densities of 80 and 31 pcf, respectively) are similar to those presented in the RI.

The RI concluded that the variability of bulk density with depth in the sediment column (as well as the variability of water content and specific gravity) was smaller than the spatial variability across sampling locations, and the bulk density within the soft sediments was therefore assumed to be relatively constant with depth.

Specific Gravity. Specific gravity has been measured in 10 sediment samples collected from OU 3, and in 2 samples collected from OU 4 as part of the RI. Results ranged from 2.32 to 2.61 with an average of 2.46, as summarized in Table 2-6 (Retec, 2002c). In addition, the USGS et al. (2004) reported the results of six specific gravity tests in OU 4, for which results ranged from 2.48 to 2.71 with a geometric mean of 2.54.

Strength and Compressibility. The USGS et al. (2004) performed unconsolidated undrained (UU) triaxial, in situ field vane shear and one-dimensional consolidation tests on several samples collected from OU 4. Results of the UU triaxial tests showed wide variability, similar to the variability seen in the in situ vane shear testing (VST) discussed below. Apparent cohesion ranged between 30 and 184 psf in the UU test. Internal friction angles varied between 0 and 11 degrees.

The results of consolidation tests performed on six samples varied significantly, with measured compression indices between 0.01 and 1.02 and initial void ratios between 0.9 and 5.15. However, the results do show good correlation between consolidation parameters (compression index and void ratio) and dry density. Given the large database of dry density data for the Lower Fox River, the USGS suggests that the available data could successfully be used to estimate consolidation properties. The effectiveness of this correlation will be further investigated as part of remedial design.

Results of five in situ field VSTs, performed 1 and 2 feet below the sediment surface, indicate that the peak undisturbed strength of the sediments range from 32 to 74 pounds per square foot (psf) with an geometric mean of 41 psf. The disturbed (remolded) strength of the sediment in the same locations ranged from 23 to 78 psf with a geometric mean of 35 psf. This suggests that up to 30 percent of the sediment strength may be lost as a result of disturbance (e.g., during and following dredging).

Permeability. The USGS et al. (2004) reported the results of six permeability tests on samples collect in OU 4. Four of the samples had permeabilities ranging from $1.4\text{x}10^{-7}$ to $4.2\text{x}10^{-7}$ centimeters per second, (cm/s) with a geometric mean of $2.4\text{x}10^{-7}$ cm/s. The permeability of one sample collected from within SMUs 20-25 showed an abnormally high permeability (1.9×10^{-5} cm/s), but this correlated well to the low percentage of fine-grained particles (7 percent by weight passing the No. 200 sieve). Similarly, the abnormally low permeability ($2.6\text{x}10^{-8}$ cm/s) of another sample correlated well to the high percentage of fine-grained particles (98 percent passing the No. 200 sieve).

Riverbed Characterization. OSI performed a survey of river bottom and shoreline conditions in June 1998 using side-scan sonar imaging, sounding data, visual observations, sampling, probing, and bottom dragging. OSI interpreted the results of this survey to classify the riverbed into five major river bottom character types, as shown on Figure 2-8, including the following:

Type I – Smooth, generally featureless. Principally soft, aqueous, silty sediments. Isolated cobbles may be present.

Type II – Smooth, generally featureless. Sand waves and scour-type features often present. Principally semi-compact to compact sands and/or clay deposits.

Type III – Appears irregular. Principally gravel, cobble deposits, and compact sand. Variable size and abundance of cobble deposits.

Type IV – Smooth with common isolated irregularities. Combination of Type II and Type III.

Type V – Extremely irregular. Principally cobble and boulder-size rocks.

As summarized in Figure 2-8, most of the Lower Fox River study area surveyed by OSI (i.e., excluding shallow inaccessible shoreline areas) was characterized as Type I, with smooth and generally featureless surface texture. However, localized gravel/cobble deposits and other irregular textures are present, especially in the vicinity of the De Pere and Little Rapids Dams. Gravel and cobble bedforms are indicative of areas devoid of soft sediment deposits and associated PCB accumulations.

2.2.4 Lower Fox River Navigational Structures

2.2.4.1 Federal Navigation Channel

The federally authorized navigation channel consists of an outer channel in Green Bay, extending 7.1 miles into OU 4 of the Lower Fox River to the De Pere Dam. However, consistent with prior requests of the local sponsor, only the downstream reaches of the OU 4 navigation channel are actively maintained. The upstream 4 miles of the authorized federal channel, extending from the Fort Howard turning basin to the De Pere Dam, are not actively maintained.

The outer navigation channel extending from the river mouth to Grassy Island is approximately 300 to 500 feet wide and 26 feet deep. From Grassy Island to the Fort Howard turning basin (RM 3.6), the authorized depth of the channel is 24 feet. The Fort Howard turning basin extends 1,700 feet upstream of the Chicago and Northwestern Railway Bridge. From the Fort Howard turning basin to the De Pere Dam, the channel is authorized to a depth of 18 feet, although this portion of the federal channel is not maintained and has been placed on “caretaker” status by the USACE. Appropriate integration of cleanup and navigation dredging activities is an important element of remedial design.

Within the channel, there are three turning basins:

- Mouth of the East River (RM 1.4) – 24 feet deep
- Fort Howard turning basin (RM 3.6) – 20 feet deep
- Base of De Pere Dam (RM 6.8) – 18 feet deep (not maintained)

2.2.4.2 Dams and Locks

There are 17 locks, 2 guard locks, and 13 existing dams (and one dam that has been abandoned) on the Lower Fox River between Lake Winnebago and Green Bay, many of which had been built by the late 1800s (Table 2-2). The dams provide hydroelectric power (11 of the 13 are licensed by the Federal Energy Regulatory Commission), navigation, and control of water levels throughout the river. The De Pere Dam at RM 7.1 separates OU 4 and OU 3. The Little Rapids Dam at RM 13.1 separates OU 3 and OU 2. The Neenah and Menasha Dams control discharge from Lake Winnebago to Little Lake Butte des Morts (OU 1). All of the remaining dams are within OU 2, where the river drops relatively steeply over Paleozoic bedrock exposures. In OU 2, the river drops 143 feet in 18.8 miles (gradient of 0.0014 ft/ft), whereas in OU 3 and OU 4 (combined), the river drops only 16 feet in 13.1 miles (gradient of 0.00023 ft/ft).

Presently, only 3 of the 17 navigational locks are in operational condition: the De Pere, Little Rapids, and Menasha Locks. The Rapide Croche Lock (in OU 2) is permanently closed to bar sea lamprey migration. All other locks would require maintenance and renovation to restore operation. Currently, the federal government is in the process of transferring control and maintenance of the locks to the state and local governments of Wisconsin. However, there are no current plans to remove any of the dams or locks.

2.2.4.3 Maintenance Dredging

Between 1958 and 2002, USACE records indicate over 16.2 million cubic yards (cy) of sediment have been dredged from the federal navigation channel, including dredging in the Lower Fox River (OU 4) and Green Bay. Although historical records available from the USACE provide only limited information for some of the previous dredging events, it is estimated that approximately 3.1 million cy of material was removed specifically from the Lower Fox River during this period (USACE, 2004a). Based on the historical records, it is estimated that on average, approximately 118,000 cy was removed from the OU 4 channel per year for the 26 out of 45 years that dredging was performed. Expressed as an annual average over the entire 45 years, approximately 68,000 cy were dredged from OU 4 annually. Since 1990 (through 2002), approximately 1.3 million cy (103,000 cy annually) of material have been dredged from OU 4B, with dredging being performed in all but 3 years.

2.2.5 Infrastructure and Obstructions

Numerous forms of infrastructure and obstructions lie within or cross the Lower Fox River (Figure 1-1). These features may provide constraints or limitations on construction operations during remediation. They include:

- Road and railway bridges;
- Locks and dams (as discussed in Section 2.2.4.2)
- Submerged pipelines;
- Submerged cables;
- Shoreline discharge or intake pipes;
- Overhead cables;
- Outfalls;
- Other submerged structures (ruins, duck blinds, cribs, etc.);
- Rocks and debris;
- Ship/vessel traffic;
- Submerged or exposed pilings and dolphins;
- Seawalls, bulkheads, and over-steepened slopes; and
- Active or inactive piers or wharfs.

2.2.5.1 OU 3

Obstructions within OU 3 include the following (Retec et al., 2003b):

- Submerged pipelines;
- Overhead cables south of Deposit EE;
- Submerged cables south of De Pere Dam through Deposits GG and HH;
- Ruins at the southern and northern ends of the OU;

- A duck blind located near the southern end of the OU; and
- Little Rapids and De Pere Dams at the southern and northern boundaries of the OU.

2.2.5.2 OU 4

Infrastructure within OU 4 includes the following road and rail bridges with horizontal and vertical clearance as indicated (Retec et al., 2003b):

- Tower Drive (RM 0.41) – Fixed-span four-lane I-43 Interstate highway bridge. Vertical clearance of approximately 120 feet;
- Wisconsin Central Railroad (RM 1.02) – Bridge is in open position except during train crossing. Unattended and controlled by train operator. Vertical clearance of 7.5 feet when closed;
- Main Street (RM 1.57) – Horizontal clearance of 95 feet. Vertical clearance of 14.9 feet;
- Walnut Street (RM 1.8) – Horizontal clearance of 95 feet. Vertical clearance of 11.8 feet;
- Don A. Tilleman (Mason Street) (RM 2.25) – Horizontal clearance of 95 feet. Vertical clearance of 32.6 feet;
- Wisconsin Central Railroad (RM 2.6) - Bridge is in open position except during train crossing. Unattended and controlled by train operator. Vertical clearance of 8.3 feet when closed; and
- Wisconsin Central Railroad (RM 3.3) - Bridge is in open position except during train crossing. Unattended and controlled by train operator. Vertical clearance of 31.1 feet when closed.

Other structures and obstructions within OU 4 include the following:

- Overhead cables at northern and southern ends of OU 4 (Retec et al., 2003b);
- Submerged pipelines and cables frequent through northern end of OU and through SMUs 26 to 31 and 32 to 37;
- 15 outfalls, one at the De Pere Sewage Treatment Facility in SMU 26 and the remainder north of the Fort Howard turning basin;
- Potentially sunken ships or barges as indicated on NOAA chart (14918) typically near the bridges;
- Archeological sites; and
- Active shipping traffic.

2.2.6 River Hydrodynamics

2.2.6.1 Lower Fox River Flows

The USGS has monitored stream flow in the Lower Fox River at several different gauging stations within the watershed. By far the longest stream gauging record is at the Rapide Croche Dam in the lower reach of OU 2 (#04084500); this record extends from 1917 to 1997. Summary statistics of Lower Fox River discharge data for the Rapide Croche Dam station are summarized in Table 2-7.

The average annual discharge at the Rapide Croche Dam is 4,308 cfs; with daily flows ranging from 141 to 24,014 cfs over the period of record. The highest discharge typically occurs during the spring months of March through June, when rivers are recharged by snowmelt and spring rains. The lowest flows typically occur in the late summer months of August and September. WDNR has developed wasteload allocations for the river based on a seven-day average low flow with a 10-year return period (Q7/10) of 953 cfs (WDNR, 1980). The USGS has estimated discharge associated with 10-year and 100-year floods at 19,211 and 24,191 cfs, respectively (Krug et al., 1992).

More recently, beginning in 1989, the USGS has operated an acoustic velocity meter in OU 4, about 0.8 miles upstream from the river mouth (Table 2-7). The average flow statistics near the mouth of the river are similar to those at Rapide Croche Dam, consistent with similar watershed areas draining to the two gauges (drainage area increases by only 5 percent between the two gauging stations). There is little additional surface water recharge, and as discussed in Section 2.2.1.3, also little gain or loss due to groundwater within this lower reach of the river. However, the main difference between the two gauges is that daily, short period oscillations of flow are observed near the mouth of the river due to seiches. Periodically, the magnitude of the seiche is large enough to cause flow reversal near the mouth. The variations in flow caused by seiches are a maximum near the mouth and decrease upstream, but the effect can be observed up to seven miles upstream to the De Pere Dam. Reversing currents associated with the seiches explains the occurrence of daily maximum discharge at the river mouth as high as 33,796 cfs in response to rebounding from a seiche event.

2.2.6.2 Lower Fox River Velocities

River velocity provides a key control of sediment deposition and erosion processes in the Lower Fox River, and is also a critical parameter for evaluation of the contingent capping remedy (Palermo et al., 1998a, 1998b; Johnson Co., 2001). Average river velocities have previously been estimated for various sub-reaches of OU 3 and OU 4 based on a consideration of the combined effects of flood flows and seiche currents. River velocities have been estimated for 10-year and 100-year peak flood events based on analyses of USGS gauging data and river cross-sections (WDNR, 1995). The estimated velocities are summarized in Table 2-8. The average annual river velocity in OU 3 is approximately 0.4 feet per second (fps), and the average river velocity in OU 4 is 0.26 fps. These average velocities are within the range of values where silt- and larger-sized particles will settle, and is consistent with the presence of extensive deposits of recent fine-grained sediments observed in these lower reaches of the river.

A more recent analysis of river hydrodynamics and sediment transport in the Lower Fox River was also performed by Baird and Associates (2000a, 2000b) as part of the Model Evaluation Work Group comprised of representatives of the FRG and WDNR. The results of this work will be incorporated into the remedial design process.

2.2.7 Sediment Transport

The Fox River is the largest Green Bay tributary in terms of discharge, drainage area, and sediment load. Over 70 percent of the suspended sediment load to the bay is derived from the Fox River (WDNR, 1999; Retec, 2002c).

2.2.7.1 Sediment Mass Balances

A sediment mass balance for OU 3 and OU 4 is presented below. Sediment transport rates were calculated from total suspended solids (TSS) measurements and concurrent flow measurements collected in 1989/1990 (WDNR, 1995; Retec, 2002c). There is a progressive decrease in sediment flux moving downstream from the Little Rapids Dam (156,500 tons per yr), De Pere Dam (88,000 tons per yr), and out the mouth of the Fox River (22,000 tons per yr). This reduction in sediment flux is a measure of net accumulation of sediment in the intervening reaches of OU 3 and OU 4.

Location	Sediment Transport Rate (tons/yr)
Little Rapids Dam (OU 3)	156,500
De Pere Dam (OU 4)	88,000
Fox River Mouth	22,000

During high flow events, both river discharge and TSS concentrations can increase significantly, as summarized in the table below (Gailani et al., 1991). As in many river systems, these data indicate suspended sediment load increases approximately as a power function of discharge. However, even at relatively high flows (15,256 cfs) approaching the magnitude of a 10-year flood (19,211 cfs), measurements performed by Gailani et al. (1991) indicate roughly one-third of the sediment load that is transported over the De Pere Dam is deposited within OU 4. At lower flows, as much as 80 percent of the suspended sediment load is deposited in OU 4. Although the sediment discharge to Green Bay also increases with increasing flow, OU 4 remains a net depositional regime over a broad range of flow conditions.

Location	River Discharge (cfs)	TSS Concentration (mg/L)	Sediment Flux (tons/day)	OU 4 Net Sedimentation (tons/day)
De Pere Dam	3,708	30	300	
"	9,888	75	1,980	
"	15,256	190	7,830	
Fox River Mouth	3,708	6	60	238 (80%)
"	9,888	57	1,540	440 (22%)
"	15,256	130	5,400	2,425 (31%)

2.2.7.2 Sedimentation Rates derived from Radioisotope Data

In 2000/2001, LTI obtained high-resolution radioisotope data from OU 3 (5 cores) and OU 4 (30 cores) to characterize sedimentation rates and mixing depths, and to identify areas of deposition and erosion (LTI, 2002c). Cores were analyzed for cesium-137, lead-210, and beryllium-7.

In OU 3, the river appears to become more consistently depositional in character moving downstream toward the De Pere Dam impoundment. The radioisotope profiles in two cores collected at the upper end of Deposit EE indicated a lack of consistent deposition.

However, three cores from approximately the lower 2 miles of Deposit EE indicated average sedimentation rates between 0.28 and 0.47 inches per year (LTI, 2002c).

The radioisotope data also indicate that the Lower Fox River below De Pere Dam (OU 4) has been a heterogeneous, but predominantly depositional environment over the past 40 years. Fine-grained sediments accumulated over broad areas of OU 4 at net deposition rates varying between 0.20 and 0.79 inches per year. There are also some areas (9 of 30 cores) where sediments are not consistently accumulating, primarily along the east bank of OU 4. These areas are characterized by coarser sand sediments (also with relatively low PCB concentrations – generally less than 0.5 ppm). These observations are consistent with local hydrodynamic conditions present in this area of OU 4 (i.e., river currents and wind wave forces) that are not conducive to sediment deposition or accumulation (LTI, 2002c).

Sediment mixing depths have also been determined from the radioisotope data collected from the LTI cores. The average mixing (i.e., bioturbation) depth in OU 4 was determined to be 3.5 inches (LTI, 2002c). Site characterization activities in the Lower Fox River (Section 2.3 below) have operationally defined the bioturbation depth as 4 inches below mudline, which is typical of sediment systems.

2.3 Lower Fox River Sediment Quality Characteristics

This section discusses the nature and extent of sediment contamination in the Lower Fox River (excluding OU 1). The discussion is focused on the spatial (horizontal and vertical) distribution of total PCBs, which is the primary chemical of concern identified in the RODs (WDNR and USEPA, 2002, 2003). This section describes the available data sources used to develop preliminary delineations of sediment PCB concentration distributions, the chemical composition of PCB mixtures (Aroclors and congeners), surface sediment PCB distributions, PCB mass distributions, and the thickness and volume of contaminated sediment that exceeds the 1-ppm remedial action standard specified in the RODs. The nature and extent of other chemicals of potential concern identified in the RODs (e.g., mercury) are also briefly discussed.

2.3.1 Data Sources

As discussed in Section 2.1, the FRDB contains sediment quality data obtained from different investigations included in the administrative record for the Lower Fox River Site. The discussion presented below focuses on prior delineations of surface and subsurface sediment PCB concentrations exceeding the 1-ppm RAL in OU 3 and OU 4, the OUs planned for active remediation, as well as Deposit DD in OU 2 and the mouth of the Fox River in OU 5.

2.3.1.1 Data Previously Incorporated Into Fox River Database

Following are the key data sources previously incorporated in the FRDB which can be used to evaluate the nature and extent of contamination in the Lower Fox River:

- **USEPA and WDNR, 1989-1990, Green Bay Mass Balance Study (GBMBS) (USEPA, 1989).** Sediment samples, including 37 coring locations, were collected in the Lower Fox River and Green Bay between April 1989 and April 1990. The thickness of accumulated soft sediments was also mapped using poling methods (see Section 2.2.3.2). The primary objective was to estimate the resident mass and flux rates of PCBs in the river-bay system (Velleux and Endicott, 1994; WDNR, 1995).
- **GAS and SAIC, 1994.** WDNR and the Fox River Coalition jointly undertook further investigation of the river reaches above the De Pere Dam to better define the lateral and vertical extent of PCB and mercury contamination. The data most relevant to the current work includes sampling and analysis of Deposits EE, GG, and HH in OU 3 (GAS and SAIC, 1996).
- **WDNR et al., 1995.** WDNR, the Great Lakes National Program Office (GLNPO), and the Fox River Coalition implemented a comprehensive sediment sampling program between De Pere Dam and Green Bay (OU 4). Because earlier studies had shown that a majority of the PCB mass in the Lower Fox River was contained in this reach, 109 locations were sampled for PCB Aroclors and conventionals (WDNR, 1998). Samples were collected from shallow gravity cores (0 to 12 inches [0 to 30 cm]) and deeper vibracores.
- **FRG, 1999-2000, SMU 56/57 Sediment Remediation Demonstration Project.** In September 1999, the FRG began a sediment remediation development (SRD) project to assess the feasibility and implementability of PCB removal in a hot spot area near the Fort Howard turning basin. In December, dredging was suspended due to the onset of winter. The Fort James Corporation continued the SRD project in summer of 2000, achieving a final removal volume of 50,000 cy. Relevant samples include post-dredge verification samples as well as other analyses aimed at quantifying the PCB budget during dredging and disposal operations.
- **BBL and Exponent, 1998.** In 1998, the FRG retained BBL and Exponent to sample 69 locations above and below the De Pere Dam. All samples were grab samples obtained from 0 to 4 inches (0 to 10 cm) (LTI, 2002a).

- **Retec, 1998.** In June 1998, WDNR and Retec collected supplemental sediment samples to support the RI/FS. Specifically, additional sampling was conducted in Deposit EE (OU 3) to a depth of 1.5 feet (45 cm), and additional surface sediment samples were collected from the areas of highest PCB concentration in OU 4 to evaluate other chemicals of potential concern (Retec, 2002c).

More recent data have also been incorporated into the FRDB by TEC INFODEX, including sediment core data collected by WDNR in OU 5 near the mouth of the Fox River, along with other relevant information.

2.3.1.2 Post-Fox River Database Information

Since the last update of the FRDB by TEC INFODEX, additional sediment quality data have been collected in the area of concern which may be relevant to remedial design, including the following:

- **BBL, 2000.** Between July and November, 2000, BBL collected sediment samples (0 to 4 inches [0 to 10 cm]) from over 100 locations between the De Pere Dam and SMUs 56/57 (denoted OU 4A). Samples were colocated on previous WDNR (1995) and GBMBS (1989/90) locations to better assess spatial and temporal changes in PCB concentrations, and to respond to peer-review comments on models for predicting the fate and transport of PCBs in the Lower Fox River (AGI, 2000). Samples were analyzed for PCB Aroclors and conventionals, consistent with earlier investigations (LTI, 2002b).
- WDNR, 2003. In July 2002, WDNR and USEPA hired Retec to conduct additional sediment sampling at 36 core locations in southern Green Bay. The objectives of the coring program were to characterize historical open-water dredged material and navigation channel side-case areas. Subsurface samples were analyzed for PCB Aroclors, TOC, and bulk density.

- **USGS et al., 2004.** In July 2003, USGS collected surface sediments (top 0.3 to 0.4 feet [9 to 14 cm]) from six locations in OU 4A, upstream of the Fort Howard turning basin. These samples were analyzed for PCB congeners (bulk sediment and porewater), and also for various geotechnical properties. Further hydrologic investigations of the Lower Fox River by USGS and others are ongoing,

Summary reports of these more recent data, including sampling and analysis plans, quality assurance project plans, and data validation reports, as available, will be provided to USEPA and WDNR for review prior to incorporating these data into the remedial design database.

2.3.2 PCB Composition in Lower Fox River

A statistical summary of PCB concentrations in OUs 2, 3, and 4, including frequency of detection, minimum and maximum detections, arithmetic and geometric mean concentrations, is presented in Table 2-9.

2.3.2.1 Aroclor Composition

Aroclor 1242 was the PCB mixture used in the emulsion applied to the manufacture of carbonless copy paper, and this mixture has been detected in over 90 percent of the sediment samples collected to date from the Lower Fox River that have been analyzed for Aroclors (Retec, 2002c). Aroclors 1254, 1260, and 1268 were detected in a smaller percentage of samples (9 to 34 percent). In addition, maximum and average concentrations of Aroclor 1242 were typically one to three orders of magnitude (10 to 1,000 times) higher than the other three detected mixtures. The remaining Aroclor mixtures (1016, 1221, 1232, 1248, and 1262) were generally undetected in the Lower Fox River.

2.3.2.2 Congener Composition

Over 150 samples collected from OU 2, OU 3, and OU 4 have been analyzed for PCB congeners, although not every sample was analyzed for the full list of congeners. Statistical summaries of coplanar PCB congeners, which exhibit "dioxin-like" toxicological properties, are presented in Table 2-9. Of the coplanar PCBs, congeners 77/110 and 118 were detected most frequently (in over 90 percent of the samples) and at the highest concentrations. However, differentiated congener 77 was detected in a smaller proportion of samples and at concentrations nearly an order of magnitude lower than undifferentiated congener 77/110. Based on these data, non-coplanar PCB congeners likely account for the majority of the mass of PCBs in the Lower Fox River. In addition, congener 105 was commonly detected, but at lower concentrations, and congener 126 was infrequently detected and only at very low concentrations.

2.3.3 Extent of PCBs in the Lower Fox River

This section describes the horizontal and vertical extent of total PCB concentrations in OUs 2 (primarily Deposit DD), OU 3, and OU 4. Following a description of PCB distributions at the site, a summary of PCB mass and impacted sediment volumes is also presented.

2.3.3.1 Horizontal Distribution of PCBs

The horizontal distribution of the maximum concentration of total PCBs at depth in Lower Fox River sediments is shown on Figure 2-9. This distribution was interpolated using asymmetrical "ordinary" kriging techniques (e.g., Isaaks and Srivastava, 1989) based on spatial correlation structures of existing site data (Section 3.1.1.1 and Appendix A). The axis of the dominant correlation scale is parallel to the flow direction of the river, such that samples oriented along the flow path are more highly correlated than samples oriented transverse to flow (i.e., between banks). Similar concentration distributions were previously developed by WDNR using an inverse-distance-weighted (IDW) interpolation scheme, as described in Technical Memorandum 2e (WDNR, 1999b). The horizontal extent of PCBs within the Lower Fox River is generally summarized in the narrative below.

OU 2 (Deposit DD). Deposit DD is the only portion of OU 2 which is planned for active remediation. The highest detected total PCB concentration in Deposit DD is 19 ppm; however, this sample represents only a very localized area within 1,000 feet of the Little Rapids Dam. The majority of surface sediments in Deposit DD are below 1 ppm (Figure 2-9).

OU 3 (Little Rapids to De Pere). OU 3 includes soft sediments in Deposits EE through HH. PCBs were detected in 83 percent of the samples, ranging from non-detect to 54 ppm. The arithmetic and geometric mean PCB concentrations in OU 3 are 5.2 and 0.63 ppm, respectively (Table 2-9).

Throughout Deposit EE, total PCB concentrations generally range from 1 to 10 ppm (Figure 2-9). The PCB distribution is patchy with localized areas below 1 ppm or above 10 ppm. There is a general trend of increasing PCB concentrations downstream toward the De Pere Dam, consistent with trends in fine-grained sediment deposits and TOC levels. The highest bulk sediment concentrations have been detected within 6,000 feet of the De Pere Dam, where fine-grained sediments accumulate behind the dam. In this area, PCB concentrations commonly exceed 10 ppm and occasionally exceed 20 ppm.

OU 4 (De Pere to Green Bay). The majority of the mass of PCBs at the site is found in OU 4. Relevant summary statistics include the PCB detection frequency (93 percent), maximum detection (710 ppm), arithmetic mean (20 ppm) and geometric mean (2.6 ppm) (Table 2-9).

In general, elevated PCBs in OU 4 surface sediments are located in the following areas:

- Immediately downstream of the De Pere Dam, in a shallow embayment on the left side of the river and in the vicinity of the former De Pere turning basin (SMUs 20, 21, 22);
- In the reach between the De Pere Dam and the Fort Howard turning basin (denoted OU 4A), where sediments are accumulating in that part of the navigation channel currently in "caretaker" status. Two particular areas include a broad reach of the river where velocities decrease (SMUs 38-41 and 44-47) and the west bank above the Fort Howard turning basin (SMUs 51, 53, 56, 57, 58). Note that much of the PCB mass in SMUs 56/57 was removed during a sediment remediation demonstration project in 1999 and 2000.
- Localized deposits downstream of the Fort Howard turning basin (denoted OU 4B) (SMUs 68-79).

In contrast, much of the east bank upstream of the Fort Howard turning basin is shallow and sandy, and evidently winnowed by waves and currents; this does not provide a favorable environment for sedimentation or PCB accumulation (LTI, 2002c). Also, much of OU 4B (downstream of the Fort Howard turning basin) is less conducive to PCB deposition because of the narrow and steep-walled channel morphology, and frequent maintenance dredging.

BBL (2000) Study in OU 4. Some significant changes in surface sediment PCB concentrations were observed in OU 4A between the 1995 WDNR and 2000 BBL investigations (LTI, 2002a). On average, surface sediment total PCB concentrations measured in OU 4A during 2000 were lower than surface sediment concentrations in 1995. However, there were a few exceptions. Most notably, increasing PCB concentrations were observed on a steep slope adjacent to the former turning basin at the De Pere Dam. This area may be subject to high energy currents in the dam-release zone, possibly contributing to oversteepening of sediments.

2.3.3.2 Vertical Distribution of PCBs

The thickness of sediments with PCB concentrations exceeding the 1-ppm RAL was estimated by WDNR using an IDW interpolation scheme, as described in Technical

Memorandum 2e (WDNR 1999b) and shown on Figure 2-10. Using the method described in WDNR, 1999b, core samples were assigned to specific subsurface intervals, and each interval was interpolated to generate a PCB concentration distribution map independent of the other intervals. The predicted concentrations in each interval were then recombined to estimate a depth of contamination at the "back end" of the interpolation process. However, this method was shown to overpredict the depth of contamination in some areas (LTI, 2002c).

An alternative approach for determining the depth of PCB contamination was developed for this RD Work Plan, and is shown on Figure 2-11. Compared to the previous estimation method, there are two main differences in this alternative approach that help to improve the accuracy of the estimated thickness and volume of PCBs above the RAL.

1. In the new method, the depth of contamination is determined directly from sediment core analytical data, whereas in the previous method, analytical data were vertically interpolated to conform to predetermined subsurface intervals (i.e., 0-10, 10-30, 30-50, 50-100 cm, etc.). This introduces an additional vertical interpolation step prior to spatial interpolation because actual sampling intervals did not conform to these model intervals.

2. The new method helps to remove some of the high bias of the previous method, which was evidenced by unrealistic extrapolation of contaminated sediments beneath areas which had been determined to be clean (i.e., non-detect or well below 1 ppm; see LTI, 2002a).

Otherwise, the interpolation was performed using the same IDW parameters as were previously used by WDNR. These revised estimates of depth of contamination will be used to guide the sampling program, specifically, the core intervals that are initially targeted for chemical analysis, as discussed further in the accompanying SAP (Shaw and Anchor, 2004a).

Figures 2-12 through 2-14 present a series of representative cross sections through the study area. The cross sections show the similarities and differences between the alternative estimates of sediment thickness with PCB concentrations above the RAL, and their relationship to other "surrogate" measures such as soft sediment thickness. Differences in estimates of sediment PCB thickness reflect the current uncertainty in the vertical extent of PCBs in the Lower Fox River based on the existing data. Resolution of this uncertainty for the purposes of designing a dredge plan for the site is a particular focus of this RD Work Plan, as discussed in Section 3.1.1.1 below.

The vertical extent of PCBs within the Lower Fox River is generally summarized in the narrative below.

OU 2 (Deposit DD). Deposit DD is relatively thin, and PCB concentrations decrease rapidly with depth (Figure 2-13). Exceedances of 1 ppm PCBs are largely restricted to the upper 1.5 feet of sediment.

OU 3 (Little Rapids to De Pere). Throughout OU 3, exceedances of 1 ppm PCBs are largely restricted to the upper 3 feet of sediment, consistent with the poling data (Figure 2-13). The thickest accumulations of sediments exceeding 1 ppm (along with the highest sediment PCB concentrations in OU 3) are located within approximately 1 mile of the De Pere Dam, including Deposits GG, HH, and the northern part of Deposit EE. Within the central and southern portions of OU 3, contaminated sediments are often less than 1 foot thick.

OU 4 (De Pere to Green Bay). The PCB accumulations in OU 4 are the thickest in the Lower Fox River. Contaminated sediments are deepest in OU 4A, typically ranging from 6 to 10 feet thick, and are somewhat thinner in OU 4B (3 to 6 feet thick) where the navigation channel is actively maintained (Figure 2-14). The thickest accumulations occur in delineated depositional areas, and generally mimic the patterns of PCB concentrations in surface sediments (Section 2.3.3.1). These depositional areas include the following:

- In the vicinity of the Fort Howard and the De Pere turning basins;
- In and around the abandoned navigation channel between De Pere and Fort Howard turning basin;
- Sections of the river where the channel broadens and velocities decrease.

In sediment core profiles from OU 4, PCBs typically exhibit a subsurface peak between 1 and 6 feet below the mudline, depending on the sedimentation rate and depositional history (LTI, 2002c). Subsurface peaks around 2 feet below mudline are relatively common. This type of profile is consistent with the rise and decline of PCB use in the drainage basin between 1954 and 1971 (WDNR, 1999a). The location of the subsurface

PCB peak is also consistent with sedimentation rates of up to approximately 1 inch per year in depositional areas, similar to rates measured using radioisotope dating methods (LTI, 2002c).

2.3.3.3 Estimated PCB Mass and Volume

The estimated mass and volume of PCBs in the various sedimentary deposits and SMUs are summarized in Tables 2-10 and 2-11, respectively. PCB mass is distributed according to depth intervals below the mudline and thus provide additional information on depth of contamination. These estimates were generated using the IDW interpolation scheme of WDNR (1999b), as modified by Retec (2002c). In addition, Table 2-12 presents an estimate of the average PCB concentration in each depth interval of each sedimentary deposit; these concentrations were estimated from the mass and volume data by assuming an average dry bulk density of 32.5 pcf (0.52 g/cm^3) for the Lower Fox River sediments (Section 2.2.3.4).

It should be noted that sediment remediation demonstration projects that resulted in removal of PCB-contaminated sediments were conducted at Deposit N and O in OU 2 and SMU 56/57 in OU 4. It appears Retec (2002c) incorporated post-remediation data in their mass and volume estimations for Deposit N, but only accounted for the first phase of removal conducted in 1999 at SMU 56/57. The mass estimates should be updated to include the second phase of removal in 2000 at SMU 56/57.

A summary of PCB mass and mean concentrations for the Lower Fox River (excluding OU 1) is shown below.

Operable Unit	PCB Mass (lb)	Percent Total PCB Mass	Estimated Mean PCB Conc. (ppm)
OU 2	205 (93 kg)	0.3 %	0.7
OU 3	2,196 (996 kg)	3.7 %	0.9
OU 4	57,327 (26,003 kg)	96.0 %	9.1

As discussed in the ROD for OUs 3 through 5, the selected cleanup remedy includes (using current estimates) removal of approximately 9,000 cy from Deposit DD in OU 2, approximately 586,800 cy from OU 3, approximately 5,880,000 cy from OU 4, and as much as 200,000 cy from the mouth of the Fox River in OU 5. Refinement of these removal volumes is a primary focus of this RD Work Plan.

Possible Interpolation Error. As discussed above, potential errors and uncertainties may be associated with the interpolation scheme used in the RI/FS for deeper sediment samples in OU 4 (LTI, 2002a). This may be caused by the relative sparseness of deep core samples and the use of a relatively broad interpolation radius (one kilometer). As a result, high PCB concentrations at depth in depositional areas were sometimes projected beneath adjacent areas with lower sedimentation rates where the base of the PCB contamination has already been defined by non-detect values. Areas with suspect interpolations are highlighted on Table 2-12. LTI (2002a) estimated that such errors may over-predict the PCB mass in OU 4 by about 7,940 lb (3,600 kg), i.e., by about 16 percent.

2.3.4 Other Constituents of Concern

A statistical summary of DDT and mercury concentrations are presented in Table 2-9 and described below.

2.3.4.1 Mercury

The distribution of sediment mercury concentrations in the Lower Fox River is shown on Figure 2-15. Mercury concentrations range from non-detect to almost 10 ppm. The arithmetic mean concentrations in OU 2, OU 3, and OU 4 are 0.8, 2.3, and 1.0 ppm, respectively.

The highest surface sediment mercury concentrations occur in the northern part of OU 3, in the last 1.5 miles of the pool above De Pere Dam. In this area, mercury concentrations range from 2 to 10 ppm. However, data are not available to evaluate the mercury distribution in the more southerly parts of this OU. In contrast, surface sediment mercury concentrations in OU 4 are generally below 2 ppm.

2.3.4.2 DDT and Metabolites (DDE, DDD)

The highest concentrations of DDT and its metabolites are generally observed in OU 3. OU 3 exhibits the most frequent detections of metabolites (18 to 22 percent detection), the highest arithmetic mean concentrations (14.2 µg/kg DDT and 10.9 µg/kg DDE), and some of the highest detected concentrations in the river (20 µg/kg DDT and 22 µg/kg

DDE). DDT and its metabolites appear to be associated with widespread non-point sources, such as agricultural runoff (Retec, 2002c).

2.4 Land Use Within the Site Area

The Green Bay and Lower Fox River areas support a population of greater than a half million people. The Lower Fox River valley, which extends from Lake Winnebago to the mouth of Green Bay (OUs 1 through 4), is the largest urbanized region in the state of Wisconsin. The Lower Fox River valley has 20 pulp and paper mills in less than 37 miles (60 kilometers). Other industries in the region include metal working, printing, food and beverages, textiles, leather goods, wood products, and chemicals. Summaries from the RI/FS (Retec, 2002b, 2002c) of the approximate land use percentages for areas within 0.25 mile of the Lower Fox River banks and the predominant land use within the OUs are shown in Table 2-13.

The largest land use along the Lower Fox River is residential. In addition, about 40 percent of the land use along the river not classified as residential or industrial/commercial represents potential wildlife habitat.

Adjacent land uses may impact the remedial design as follows:

- Type of dredge – noise and air impacts to the surrounding area could affect the selection of electric or diesel dredges.
- Working hours – construction noise impacts could limit activity daylight hours only in residential areas.
- Type and placement of auxiliary equipment – construction staging areas, location of pipeline booster pumps, pipeline routes, truck haul routes, etc. could be impacted by adjacent land uses, right-of-ways, or availability of space.

The Green Bay Harbor navigation project extends into OU 4. The federal channel is maintained from Green Bay to the Fort Howard turning basin. The remaining portion of the federal channel from the Fort Howard turning basin to the De Pere Dam is not maintained at this time. As discussed above, appropriate integration of cleanup and navigation dredging activities is an important element of the remedial design.

2.5 Existing Habitat Conditions

2.5.1 Habitat and Wildlife Overview

Terrestrial habitats in the Lower Fox River watershed are primarily open land and woodland. Open land habitat is predominantly agricultural or open meadows and is the largest habitat within 0.5 mile of the Lower Fox River (Retec, 2002a). Woodland habitats are in decline in the Lower Fox River basin and are present mostly in thin, elongated areas along roads or fields (Retec, 2002a). Development of agricultural and urban areas has caused a reduction in woodland habitat in the Lower Fox River area.

Aquatic habitats within the Lower Fox River Site include wetland, riverine, and lacustrine communities. Wetland habitats in the Lower Fox River are the most critical habitat for wildlife (Retec, 2002a). In 1998, only 334 acres of wetlands were present within 0.25 mile of the Lower Fox River's shore. Eighty-eight percent of these wetlands exist above the De Pere Dam in OUs 2 and 3 (Exponent, 1998). Three types of wetlands are found in the Lower Fox River area: emergent/wet meadows, scrub/shrub wetlands, and forested wetlands. Submerged aquatic vegetation (SAV) is associated with wetland areas and provides habitat for juvenile fish, waterfowl, and invertebrates. SAV is present in higher amounts immediately upstream of the De Pere Dam (OUs 2 and 3) than below the dam. Riverine areas occur in OUs 2 through 4; lacustrine habitat is found only in OU 5.

Cities, villages, commercial and industrial areas represent the urban environment in the Lower Fox River. Agriculture in the area includes orchards, cropland, and pastures (Retec, 2002c). Much of the shoreline has been developed to accommodate these activities, especially in OUs 3, 4, and 5. The shoreline here is predominantly bulkheads or riprap, and optimal habitat for wildlife, such as wetlands or wooded riparian areas, are rare.

Wildlife in the Lower Fox River area includes mammals, fish, birds, and reptiles. Mink are a semi-aquatic species that has suffered a population decline largely due to channelization of the river (Retec, 2002a). Mink are associated with brushy or woody riparian areas in the Lower Fox River; they forage in slow-flowing waters surrounded by marsh vegetation or downfall and debris. Otters are another mammal with a declining population in the Lower Fox River, with habitat requirements similar to those of mink.

Fish are an important component of the wildlife population in the Lower Fox River system. Many species such as walleye, yellow perch, white bass, northern pike, and salmon are desirable recreational fishes, and also comprise an important part of the Lower Fox River food web (WDNR, 2002). In addition, lake sturgeon (*Acipenser fulvescens*) is an important species to Native Americans in the area. The Menominee Indians used lake sturgeon for food, cultural and spiritual purposes. Lake sturgeon has been listed in the region as a threatened species due to declines from discarded bi-catch and a directed fishery that existed in the 1800s and 1900s. In 1966, less than one percent of the 1880 catch was landed in Lake Michigan (Retec, 2002c). There are only a few areas in OUs 4 and 5 where lake sturgeon are known to spawn (Retec, 2002a).

Walleye are also a popular sport fish in the Lower Fox River area. Through the mid-1970s, low dissolved oxygen conditions and other unfavorable habitat conditions appeared to limit the populations of fish such as walleye in the Lower Fox River. With improved water quality characteristics in the river resulting from wastewater treatment controls, walleye populations improved, aided by a stocking program that began in the Lower Fox River in 1973. Now, self-sustaining walleye populations exist in Fox River and Green Bay (WDNR, 2002).

Endangered or threatened bird species in the Lower Fox River basin include the osprey, common tern, Forster's tern, Caspian tern, and snowy egret. Important habitats for these birds include wetlands, wooded shorelines, and beach areas. Bald eagles and double-crested cormorants are two species in the area with growing populations that appear to be attributable to protective measures.

The Lower Fox River is also home to a number of introduced species, including Eurasian water milfoil, zebra mussels, rainbow smelt, alewife, carp, and brown trout (Retec 2002a, WDNR, 2002). Many of these species have negatively affected the native wildlife and habitats in the area.

2.5.2 Habitat Description by Operable Unit

As discussed in Section 2.2 above, dams, locks, and other man-made feature of the Lower Fox River influence other physical characteristics of the river system. OU 2 contains several dams and locks and thus has variable flows, sediment characteristics, and associated habitats. OUs 3 and 4 are delineated by locks and dams, but do not contain any other dams within their contiguous reaches. The flows and sediment compositions are less diverse in these OUs. OU 5 extends into Green Bay from the mouth of the Fox River and does not contain any locks or dams. Dams and locks on the Lower Fox serve navigational and hydropower purposes, although only three of 17 navigational locks are currently operational (Retec, 2002c).

2.5.2.1 OU 2

Habitat conditions and river flows in OU 2 are variable due to the physical characteristics (flow, gradient) dictated by the large number of dams and locks on this section of the river. Surface sediments in OU 2 are comprised of 15 percent silty sediments, 7 percent semi-compact to compact sands or clay, 77 percent compact sand and gravel, and 1 percent other sediments (WDNR, 2002).

Forty-one percent of the shoreline of upper OU 2 (above Cedars Lock) is developed as residential and urban/commercial properties (WDNR, 2002). Below Cedars Lock, residential development increases as the river narrows, and flow velocity also increases. Undeveloped areas have natural shoreline with overhanging vegetation in OU 2. OU 2 has a number of tributaries, which provide small wetland habitat with SAV and several clusters of islands used by wildlife.

2.5.2.2 OU 3

Flows in OU 3 are variable, with riffle runs below Little Rapids Dam, and deeper water and slower flow velocities near De Pere. Surface sediments on OU 3 are comprised of 85 percent silty sediments, 4 percent semi-compact to compact sands or clay, 6 percent compact sand, gravel, and cobble, and 5 percent other sediment types (WDNR, 2002).

Habitat types are less diverse here than in the upper parts of the Lower Fox River. The land use is mostly agricultural, but towards De Pere, urban and commercial land becomes more common. There are few habitat structural attributes in OU 3. Tributaries provide wetland and backwater habitat along small areas of natural shoreline (WDNR, 2002).

2.5.2.3 OU 4

OU 4 has relatively low current velocities, averaging only 0.26 fps (Retec, 2002c). The river is channelized and narrowed for navigation here, and surface sediment in OU 4 is 95 percent silty by composition, with 3 percent semi-compact to compact sands or clay and 1 percent compact sand, gravel, and cobble deposits (WDNR, 2002).

The shoreline in OU 4 is generally industrial, commercial, or residentially developed and less natural shoreline and terrestrial habitat occurs here compared to other parts of the river. Twelve percent of the shoreline is identified as natural (WDNR, 2002); bulkheads and riprap are the most common shoreline types in this section of the river. Few wetlands are present and SAV and emergent aquatic vegetation are found only in low density. Water clarity is low in OU 4 due to frequent phytoplankton blooms, silt loads, and urban runoff. Walleye adults have been associated with submerged structure in OU 4, and white bass and white perch are attracted to warm water discharges in this area. One active bald eagle nesting site is present in this area (Retec, 2002a).

2.5.2.4 OU 5

OU 5 is mostly lacustrine habitat in an urban, industrialized setting. The shoreline is nearly entirely industrial, commercial, or residential. Bulkheads and riprap are common along the shoreline. However, several wildlife sanctuaries maintained by the City of Green Bay are present in this area.

2.6 Pre-Design Dredging Evaluation

This section describes the dredge plan development process for the removal of contaminated sediment from OU 3 and OU 4. Sediment from Deposit DD in OU 2 is also included as part of the OU 3 removal. The remainder of OU 2 was selected for MNR under a separate ROD for OU 1 and OU 2 (WDNR and USEPA, 2002). As stated in the ROD for this project (WDNR and USEPA, 2003), limited dredging may be required at the River mouth in OU 5 after further characterization of that area. This dredging would part of the OU 4 removal.

The following steps describe the process that will be followed during the dredge pre-design and the sections below expand upon these items:

1. Define extent of required cleanup.
2. Generate design criteria.
3. Evaluate river data from past sampling events to determine its sufficiency for use in the design.
4. Consider relevant experience gained during the pilot demonstration removal projects at Deposit N and SMU 56/57 and during any pilot projects or remedial action at OU 1. These projects provide information regarding the effectiveness of dredging equipment,

containment systems, and dewatering operations that may be applicable during the remedial design.

5. Assess potential environmental impacts during construction.

6. Assess the need for any supplemental data required to assess potential environmental impacts and complete a dredge plan, then obtain this information.

7. Develop a preliminary dredge plan that integrates the above data, information, and experience. The dredge plan will include delineation of the required dredge prism, construction sequencing, equipment selection, best management practices (BMP), and other key factors.

2.6.1 Extent of Required Cleanup

As previously discussed, the ROD establishes a RAL of 1 ppm PCB for this cleanup effort. Specifically, any sediment with PCB concentrations greater than 1 ppm will initially be targeted for removal. The success of the project will be determined by reaching the dredge elevation that represents the removal of material with a PCB concentration greater than 1 ppm. If post remedial samples show that the 1-ppm RAL has not been achieved, then the effectiveness of the PCB removal will be dependent upon reaching the SWAC of 0.26 ppm in the top 10 cm of sediment for OU 3 and 0.25 ppm for OU 4. The ROD provides additional options to further reduce risk, if a SWAC has not been achieved. These options include undertaking additional dredging or placing a sand cover on dredged areas to reduce surficial concentrations such that the SWAC is achieved.

Based on an initial review of the available data (see Section 2), it is possible that in addition to collecting chemistry data within the project site, surrogate data can be used to inform the dredge plan design in appropriate areas of the Site. Specifically, poling data and sub-bottom profiling may provide useful design-level information to interpolate the thickness of soft (i.e., recently deposited) sediment layers between core locations, particularly in areas where PCB concentrations have a high likelihood of exceeding the RAL. That is, the surrogate data will be used in conjunction with detailed sediment core data collected in summer 2004 to define the required extent of cleanup, which is the primary criteria used to develop the dredge plan design.

The PCB concentration data will be analyzed to determine whether and how closely a correlation exists between the PCB contamination and surrogate data, as generally depicted on Figures 2-13 and 2-14. If the apparent correlation observed to date is confirmed by the summer 2004 core sampling, the surrogate information will be applied to interpolate contaminated sediment thickness between core locations, and thus to inform the dredge plan design. The subsections below briefly discuss the surrogate data and PCB data that will be used to establish the correlation.

2.6.1.1 Extent of PCB Contamination

Sediment cores and PCB data have been collected during various investigations (Section 2.3.1.1). Information collected by WDNR has been used to preliminarily define PCB contamination at depth. The thickness of PCB-contaminated sediment greater than 1 ppm as calculated by WDNR is presented in Figure 2-10. As discussed above in Section 2.3.3.2, an alternative estimate of PCB thickness using ”depth of contamination” as an index parameter was developed for this RD Work Plan and is summarized on Figure 2-11. Representative cross sections through the study area are presented in Figures 2-13 and 2-14, and depict differences between the alternative PCB thickness estimates and their relationship to other surrogate measures such as the soft sediment thickness. Differences in estimates of sediment PCB thickness reflect the current uncertainty in the vertical extent of PCBs in the Lower Fox River, based on the existing data. Resolution of this uncertainty for the purposes of designing a dredge plan for the Site is a particular focus of this RD Work Plan, as discussed in Section 3.1.1.1 below.

2.6.1.2 Sub-Bottom Profiling

Sub-bottom profiling data were collected by WDNR in late 2003. These data will be evaluated to characterize subsurface sediment characteristics (e.g., debris delineation), and to determine whether a correlation exists between the sub-bottom data (i.e., travel time to the native contact reflector) and the thickness of the soft sediment layer. The soft sediment thickness as inferred by the sub-bottom profile data may be used as surrogate information in developing the dredge plan design.

2.6.1.3 Poling Survey

As described in Section 2.2.3.2, soft sediment thickness was measured by pushing a 2.5-inch diameter aluminum sounding pole through the sediment until the depth of refusal (Figure 2-5). These data will be evaluated to determine whether a correlation exists between soft sediment thickness and depth of contamination. As discussed above, if the preliminary correlation as generally depicted in Figures 2-13 and 2-14 is verified by the summer 2004 core data, soft sediment thickness may be used as surrogate information in developing the dredge plan design.

2.6.2 Dredge Plan Design Considerations

The dredge plan design is developed to take into account many factors; however, the primary objective of the dredge plan is to ensure that contaminated sediment that is required to be removed fall within the horizontal and vertical extent of the dredge plan design to the degree that is feasible. The main criterion of the dredge plan is to incorporate the extent of contaminated sediment with PCB concentrations above 1 ppm. A preliminary delineation of the horizontal and vertical distribution of PCB concentrations that exceed the 1-ppm RAL is discussed in Section 2.3 and shown graphically on Figures 2-9 through 2-14.

Once the required extent of cleanup is defined, by using existing data and new data to be collected, the required dredge elevations will be set at or below the bottom of the contaminated sediment layer to ensure that the contaminated sediment above the required dredge elevations will be removed. Because of the inherent lack of positioning accuracy of dredging equipment, the required dredge elevations are typically specified as a constant elevation over a specific area, referred to as a dredge management unit (DMU). A final dredge plan typically resembles a patchwork of multiple DMUs, each DMU with a different required dredge elevation. The required dredge elevations will vary depending on the thickness of contaminated sediment above the RAL at any specific location. DMUs will be developed to encompass adjacent areas with similar required dredge elevations and physical properties. These DMUs will be sized appropriately (i.e., dredge cut widths and lengths) to maximize the efficiency for the selected dredging equipment.

Because the required dredge elevations in the dredge plan will always be at or below the bottom extent of contamination, the dredging will result in removal of sediment that does not exceed the RAL, providing a contingency against leaving contaminated sediment in-place. Also, due to dredge equipment tolerances, the dredger is required to dredge below the required dredge elevation in order to remove all sediment above that line. Dredging below the required dredge elevation is termed overdepth dredging, and it is standard practice to specify an allowable overdepth. The allowable overdepth represents an additional contingency to ensure that contaminated sediment is removed.

A conceptual dredge plan cross-section is presented in Figure 2-16. This section conceptually illustrates the dredge prism in relation to the existing mudline, sediment cores, navigation channel limits, soft sediment thickness, and the depth of PCB-contaminated sediment above 1 ppm. To account for dredging equipment tolerances, an allowable overdepth line is included. A detail showing a conceptual example of a required setback from infrastructure is also provided in the figure.

There are numerous factors that affect the ability of a dredging contractor to effectively and efficiently dredge a complex site. These factors are important to consider in developing the required dredge prism and are discussed below:

2.6.2.1 Extent of Required Cleanup

Once the extent of contamination is identified, this information will be used to develop the required dredge prism, along with other key design considerations (Section 2.6.1).

2.6.2.2 Infrastructure and Obstructions

The infrastructure and obstructions identified in the project area from bathymetric surveys, side-scan sonar surveys, sub-bottom profiling, and other sources of information available for the Lower Fox River, as discussed in Section 2.2.5 will be superimposed onto the dredge prism. The dredge plan will contain necessary setbacks to avoid undermining existing structures during dredging activities. Areas containing submerged items such as pipelines, cables, or ruins may inhibit the use of a dredge in that area. In addition, rock and debris may also inhibit dredging and may require removal prior to dredging when feasible. In areas of excessive debris and obstructions, dredging may not be possible and the implementation of the contingent capping remedy may be required (Appendix B).

The existing information on large infrastructure and overhead obstructions is sufficient in showing their locations, but lacks the structural information required to develop required setbacks. Structural surveys and a historical record drawing search will be needed to develop these setbacks. The submerged obstructions mentioned in Section 2.2.5 will require verification and additional surveys will be necessary to identify any new obstructions. A side-scan sonar survey conducted by WDNR in late 2003 will be evaluated to verify the existence of known submerged items and debris and to identify any new items on the sediment surface.

2.6.2.3 Sub-Bottom Profiling

Sub-bottom profiling data were collected by WDNR in late 2003. This data will be evaluated during the remedial design to determine the subsurface sediment characteristics and the locations of buried items.

2.6.2.4 Federal Navigation Channel

A federal navigation channel, as described in Section 2.2.4.1, extends the length of OU 4. The authorized depths are -24 feet from the river mouth to the Fort Howard turning basin and -18 feet from the Fort Howard turning basin to the De Pere Dam. The channel is not maintained between the De Pere Dam and the Fort Howard turning basin. Some of the contaminated sediment requiring removal lies within this unmaintained navigation channel. It is important to identify the limits and authorized depths of the federal navigation channels to ensure that the proposed remediation plan does not impact the authorized limits and depths. For dredging activities, this should not be an issue. Should the remediation plan involve both dredging and capping (to manage residuals for example), then the authorized channel will need to be considered as part of any planned capping (Appendix B). Dredging activities may also be integrated with Corps channel maintenance operations and other federal authorities, as appropriate.

If there is a navigation improvement that occurs as part of this project, including maintenance of the existing navigation depths, there may be an opportunity to procure or leverage federal funding into an integrated cleanup/navigation project. Typically, federal funding would be requested by a local sponsor and an economic evaluation would be required to justify funding the proposed dredging. The local sponsor would sign a Project Cooperation Agreement (PCA) with the Corps District in order to cost share the project components considered to be navigation related.

The Detroit District with WDNR as the local sponsor, is currently developing a scope of work and cost sharing agreement to complete a WRDA Feasibility Study on the Lower Fox River. Many elements of the Feasibility Study data and analysis requirements could overlap with the remedial design requirements. As a result, there may be an opportunity for WDNR to use some of this effort as in-kind services for a portion of the local sponsor’s Feasibility Study cost share. These opportunities will be evaluated during the remedial design.

2.6.2.5 Bathymetry

The USEPA FIELDS program collected bathymetric data in fall 2002 (October and November). This bathymetric data will initially be used in conjunction with the depth of contamination and other surrogate information to determine the required dredge cut elevations. These bathymetric data will be replaced with data scheduled for collection by Retec, WDNR's contractor, during Summer 2004.

The Retec Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) for the proposed bathymetric surveying (Retec et al., 2003a, 2003b) was reviewed. The proposed bathymetric survey work in the SAP/QAPP appears adequate to use for design purposes. However, if the data are not adequate, a focused supplemental survey may be necessary to complete the design.

Bathymetry is also an important factor in the selecting dredging equipment, since water depths can limit equipment effectiveness. This is discussed in further detail in Section 2.6.4.5.

2.6.2.6 Site Geotechnical Properties

The geotechnical properties of the dredge material, in an in situ and ex situ state, and existing geotechnical properties of the adjacent bank slopes are important factors in developing the dredge plan. The geotechnical properties of the dredge material in an ex situ condition will help evaluate transport and disposal site issues. In situ properties will help evaluate dredgeability, production rates, and feasibility of backfill and the contingent capping remedy (as appropriate). Typical sediment physical characteristics include water content, organic content, grain size distribution, Atterberg limits, bulk density, and specific gravity.

Geotechnical properties of the adjacent banks are critical to evaluate the potential for slope failure as a result of dredging. Further discussion of slope setbacks and dredgeability can be found below:

Slope Setbacks. For cases where the extents of required cleanup extend into a bank that can not be feasibly re-graded, the required dredge prism will need to be set back away from the toe of the existing bank slope to avoid undermining that slope. An alternate remedial action (such as in-place capping/sand cover, enhanced natural recovery or

Monitored Natural Recovery) will be required to manage the remaining contaminated sediment.

Dredgeability. Dredgeability refers to the physical characteristics of the proposed dredge material and how readily the material can be dredged using different pieces of equipment. The typical measurement of dredgeability is the relative density of the in situ sediment, which can be measured using the Standard Penetration Test (SPT) and is expressed in blow counts (N-value). In general, the higher the SPT blow count, the harder the material is to dredge. Based on the results of previous investigations, including soft sediment poling data, the material within the dredge prism is expected to be very soft, and will likely exhibit very low or even zero (i.e., weight of rods) blow count readings. Therefore, extensive SPT testing within the soft sediments comprising the dredge prism will not be conducted. Instead, the relative measure of in situ density will be obtained using the core logs from vibracores. However, SPT testing will be performed in geotechnical borings advanced along the side slopes to support slope stability analyses. Although the intent of these geotechnical borings will be to characterize the sediments below the dredge prism, SPT measurements within the soft sediment layer will be taken to confirm the assumption regarding the relative density of the soft sediments. These SPT measurements will be used to extrapolate the relative density of the surficial soils to the other portions of the river, based on correlations of other geotechnical properties (i.e., moisture content, grain size, etc.).

Dredgeability is also affected by the material being excavated. Loose soft sediment such as maintenance dredge material is considered to be easily dredged; native material consisting of stiff clay or gravel layers are considered more difficult to dredge. Dredgeability of the material affects the type of equipment selected to perform the dredging.

The material characteristics for OU 3 and OU 4 indicate that the materials to be removed will consist of sands and silts, with some clay component. Detailed analysis of the grain-size curves will be used to determine the ability to hydraulically transport the material (e.g., horsepower required for booster pumps), the ability to cut and remove the sediments, and the potential for inclusion of any coarser-grained sediment that may inhibit production. Additionally, the proportional makeup of the material by reach will assist in determining the best method for removing and rehandling the sediments and the technologies to be employed to effectively remove the material and the contaminants. Sufficient material sampling and physical analysis would be necessary to make these choices and further sampling data is required based on the sampling conducted to date.

2.6.2.7 Side Slopes and Overdepth

In order to ensure stable slopes, the design will incorporate slope analysis to minimize the potential for slope sloughing. Slope surveys and the collection of additional slope geotechnical samples, from the geotechnical borings discussed above, are necessary to adequately design slope setbacks.

To account for dredging equipment capabilities, an allowable overdredge depth tolerance will be included as part of the design. The appropriate overdepth for this project will be determined during the design phase.

2.6.2.8 Construction Sequencing

Construction sequencing is dependent upon multiple considerations. Some key considerations include:

1. Site accessibility and timing of access at various cleanup areas.
2. Seasonal restrictions (e.g., construction closure windows, ice and storm conditions, high or low flow conditions that affect water depth or current velocities).
3. Sequencing of work locations to minimize residuals (i.e., dredge from upstream to downstream, and/or dredge most contaminated locations first to minimize potential for recontamination of newly remediated areas).
4. Depending upon the selected disposal site, and the method for transport of dredged sediment, there may be a need to sequence the locations of work to accommodate staging areas or pipeline layouts.
5. Determine which sections of river will be remediated during which year. Since the remedial action is anticipated to take multiple years, the dredge plan sequencing needs to take into account source control, potential for recontamination, and other long-term factors.

2.6.2.9 SMU 56/57 and Deposit N Experience

The SMU 56/57 and Deposit N Demonstration Projects resulted in several lessons learned that will be evaluated during this dredge design. These lessons, as described in Appendix B of the FS (Retec, 2002b), include:

- The horizontal augerhead used in 1999 for the SMU 56/57 project produced a sediment slurry with 4.5 percent solids, a value below their target goal. This will be considered in terms of equipment selection.
- Debris was encountered during the SMU 56/57 project that hindered progress and production rates. This will be considered in terms of better defining debris areas and debris removal strategies.
- The FS suggested that for the 1999 SMU 56/57 project, the dredge needed shorter cables, better positioning, and more overlapping transects to better remove sediment ridges. This will be considered in terms of equipment selection.
- During the 1999 SMU 56/57 project, target elevations weren't achieved due to the early onset of winter. This resulted in some areas where significantly higher PCB concentrations were measured in the surface sediment in areas not fully dredged. This will be considered in terms of specifying not leaving higher contaminated surfaces in between dredge seasons.
- Large areas of bedrock made full removal and verification difficult during the Deposit N project. This will be considered in terms of obtaining adequate subsurface characterization to assess dredgeability prior to finalizing the dredge design.
- Standard water treatment technologies were successful in meeting effluent standards during the Deposit N and SMU 56/57 Phase II pilot projects. The type of treatment used will be considered during this design.
- Silt curtains were occasionally disturbed by passing vessels and required repair. This will be considered during the development of environmental BMPs during the design. Other options such as operational control of the dredge may be evaluated as an alternative to the use of silt curtains, especially in the OU 4 navigation channel.

2.6.3 Preliminary Dredge Volumes and Production Rates

2.6.3.1 Dredge Volume Estimates in the ROD

Preliminary dredge volumes were presented in the ROD (WDNR and USEPA, 2003). An estimated 595,800 cy were calculated for removal from OU 3 (including Deposit DD in OU 2) and 5,880,000 cy were calculated for OU 4. Additional dredging at the river mouth in OU 5 may be required. Delineation of this area will be conducted during the pre-design sampling activities (Section 3.1). These estimated volumes will be adjusted during the preliminary design as the extent of required cleanup is more fully defined, and also as the dredge prism is created to accommodate design considerations and overdepth allowances.

2.6.3.2 Methodology for Volume Calculation

A three-dimensional surface will be created for both the existing bathymetry and the required dredge prism with the allowable overdepth. These surfaces will each consist of a set of contiguous, non-overlapping triangles known as a triangulated irregular network (TIN). Using specialized computer software (such as AutoDesk Land Desktop), the volume between these two TINs will be calculated to represent the design dredge volume.

2.6.3.3 Estimated Daily Production Rates

Upon completion of the draft Basis of Design Report, the Respondents will have an updated delineation of the volume and area of sediments covered by specific dredging recommendations. This report will also identify dewatering, transportation, treatment and disposal options, all of which affect the daily dredging production rates. Estimated production rates will be calculated based on equipment effectiveness and cost efficiencies realized with various timeframes.

2.6.4 Equipment Selection Considerations

The ROD specifies using an "environmental dredge" (e.g., cutterhead or horizontal auger or other) with in-water pipelines to carry the dredge slurry from the dredging area to a staging area, and then via pipeline to a passive dewatering facility. The primary method of removal specified in the ROD will be through hydraulic dredging and pipeline transfer. However, mechanical dredging via barge mounted derrick with clamshell bucket (or environmental bucket if feasible) or barge-mounted excavator may be necessary in localized areas where bathymetric conditions, access restraints, infrastructure, or other obstructions prevent the use of a hydraulic dredge. Depending upon potential disposal area site constraints (such as transportation corridors and right-of-ways, transport distances, management and potential treatment of dredge slurry water, and dewatering site sizing requirements), mechanical dredging and transport may be a more effective method for removing contaminated sediment. Dry excavation using land-based equipment also may be considered in shallow areas near the shoreline.

Selecting appropriate dredging equipment will be dependent upon multiple criteria, and may require compromise in order to achieve the best overall results from an environmental impact, institutional impact, cost, and scheduling standpoints. Some of the main issues to consider when selecting appropriate equipment include:

1. Availability and types of equipment
2. Production rate capability
3. Navigation access for vessels transiting the river
4. Minimization of short-term water quality impacts
5. Water depths
6. Thickness of contamination above 1 ppm PCB
7. Currents
8. Presence of significant debris and dredgeability of dredge material
9. Removal efficiency
10. Contaminant resuspension
11. Disposal site capacity and water management of hydraulically dredged sediment
12. Accessibility of equipment into various cleanup areas

The following sections briefly discuss the criteria for selecting equipment as listed above.

2.6.4.1 Availability and Types of Equipment

The availability and types of dredge equipment within the local market will be assessed. If local contractors are unable to furnish adequate equipment during the project construction period, the availability of equipment from outside the area will be considered with an emphasis on the least costly alternative that provides equipment acceptable to meet ROD requirements. It is anticipated that some specialty applications of equipment (or combinations of equipment) will be assembled specifically for the project to suit the project constraints. Interest in the project will likely come from firms throughout the nation.

2.6.4.2 Production Rate Capability

Different types of equipment have varying production rate capabilities. The potential schedule impact and resultant risk management and cost considerations associated with the use of different equipment will be evaluated as a part of remedial design.

2.6.4.3 Navigation Access for Vessels Transiting the River

Portions of the Lower Fox River may have significant vessel traffic. Safe navigation of vessels using the river for transit typically takes precedence over construction activities; therefore dredging specifications will require the contractor to not impede commercial navigational access (either commercial or recreational). Certain equipment can cause a greater navigational hazard and impediment, such as floating pipeline, or long anchor lines for holding a floating derrick in position. The dredge plan will consider the impact of certain equipment on navigational access.

2.6.4.4 Minimization of Short-Term Water Quality Impacts

It will be important to select equipment that minimizes to the extent practical short-term water quality impacts (including resuspension of sediments). See Section 2.6.5 for additional discussion on the minimization of short-term water quality impacts.

2.6.4.5 Water Depths

Water depths can affect equipment selection due to limitations of certain types of dredges in either deep or shallow waters. The relatively shallow depths near shore will require smaller equipment whereas the deeper areas, e.g., navigation channels, may require the use of a larger sized plant. The predominant dredging plant possibilities for project execution consist of hydraulic augerhead or cutterhead dredges, mechanical clamshell dredges and mechanical backhoes. Some combinations of these may also be implemented.

Augerhead dredges are normally smaller dredges (less than 12-inch discharge) and typically work in water as shallow as 2 feet and as deep as 20 feet. Cutterhead dredges (under 12 to 14-inch discharge) can handle deeper depths with a range from 3 feet to 30 feet. Hydraulic cutterhead dredges may be preferred over augerhead dredges if the dredge cut is deep. However, in deep water, certain hydraulic equipment can have limitations due to maximum ladder lengths.

Mechanical dredges, or hybrid mechanical/hydraulic, may be suggested if the dredging areas are concentrated or are erratic in shape. Clamshell dredges can handle deep digging greater than 30 feet and backhoe dredges normally are shallower in operating depth. Typical barge-mounted backhoes can handle digging depths up to 25 feet. However, mechanical dredges require a method of transport of the material to the disposal site that could dictate the minimum working depths of the dredge. If barges are used to transport material, the draft of the loaded barge can be the limiting factor in restricting the mechanical dredge to the deeper dredging areas (e.g., greater than 8 feet). Hybrid combinations of mechanical excavation and hydraulic transport have been used in the past and therefore would not have the same minimum depth restrictions.

Recommendations will be made as to the type of dredging equipment that may be best suited to remove material while considering water depth restraints. It is possible that multiple dredging plants would be required to optimize the sediment removal.

2.6.4.6 Thickness of Contaminated Sediments Above 1 ppm PCB

The cut thickness that a dredge can attain will be a consideration when selecting equipment. The thickness of the required dredge cut (based on exceeding the 1 ppm PCB RAL) combined with the water depth (see above) will influence the type of dredge as some dredges are better suited for either thick or thin dredge cuts. Hydraulic dredges, for example, may be preferred over augerhead dredges if the dredge cut is deep. As discussed above, it is possible that multiple dredging plants would be required to optimize the sediment removal as various contamination thicknesses are expected.

2.6.4.7 Currents

Currents in OU 3 and OU 4 have average stream flow velocities of 0.40 fps and 0.25 fps, respectively (Table 2-7), with higher peak velocities occurring during seasonal runoffs or storm events. Currents are not always linear with the navigation channel and their course and strength must be considered in the choice of equipment deployed or technologies used. Currents affect the various types and sizes of dredging plants differently. For hydraulic dredges, currents can impact swinging or traveling, whereas for mechanical clamshell-type dredges, currents can affect the accuracy of bucket placement. In extreme flow conditions, operations may even be temporarily halted. Consideration will be given as to the anticipated operational currents and their seasonal occurrences, and their impacts on the plants, techniques, and sediments.

2.6.4.8 Presence of Significant Debris and Dredgeability of Dredge Material

Significant quantity of debris will impact the ability of different equipment to effectively dredge an area. For example, hydraulic equipment is not effective at excavating and transporting larger debris. This may be an issue given the experience gained from SMU 56/57. The dredgeability of the material affects the ability to feasibly use certain environmental dredging equipment. Environmental buckets, such as the closed bucket, are not effective at dredging consolidated sediment due to the lighter weight nature of the bucket and lack of digging teeth.

2.6.4.9 Removal Efficiency

The removal of the sediments encompasses multiple factors for consideration. Each dredging area that is defined will necessitate a certain type of plant and methodology to remove the sediments. Certain processes will have greater efficiency in removal of the contaminated sediments, and each will have its own related efficiency in removal of excess material or overdepth.

In deciding the equipment to employ, the potential of each methodology to optimally remove the highest percentage of contaminants with the least amount of effort will be evaluated. Hydraulic methods are effective in removing the sediments, but have some difficulty in minimizing the removal of additional non-contaminated materials. This will be considered when large volumes of sediments and deep dredge cuts are envisioned over sizeable areas. In areas where more precise control over limiting the addition of non-contaminated materials is necessary, or where more precision dredging around structures, etc is required, mechanical means will be reviewed for optimizing the removal of the sediments. In certain cases where rock or other impediments may be restricting the accessibility of a mechanical bucket, a smaller hydraulic dredge may be recommended to assure removal of the trapped sediments.

Recently, dredging contractors have begun to employ more sophistication in the methodology of removal of contaminated sediments. Attempts at providing more precision include using mechanical backhoe excavators and clamshell buckets equipped with multiple sensors to provide tight vertical control over excavation efforts.

2.6.4.10 Contaminant Resuspension

Hydraulic dredges typically cause some resuspension of sediments around the active cutting device, but the suction effect of the dredge minimizes its impacts. Augerhead dredges can provide additional restraint over resuspension by using a shroud over the auger to contain the sediments.

Mechanical dredges must be equipped with covers or other closure and sealing devices to prevent resuspension of sediments while passing through the water column. Mechanical dredges also have the slight potential to re-introduce contaminants back into the water column depending upon the method of transfer of the material from the barge to the disposal facility.

Resuspension can be controlled (depending on site conditions and operational characteristics) by strict quality control in the maintenance and adherence to operational procedures. In evaluating the choice of dredging method for each area, consideration will be given to the selection of the methodology that minimizes the re-introduction of material into the water column and the reduction in resuspension of contaminants.

2.6.4.11 Transport, Dewatering, and Disposal Considerations

The available disposal options influence the dredge plan design. The disposal site footprint, the distance from the dredging area, the availability of pipeline easements from the dredging area to the disposal site, and the capacity of the site to decant excess water from dredged material slurry are just some of the disposal site factors which may dictate the type of dredged material transport. The feasibility of hydraulic or mechanical transport to a disposal site, in turn influences the dredge plan design. Specific disposal options for this project are discussed in Section 2.7.

The following paragraphs discuss how the transport, dewatering, and disposal of dredged material affect dredge equipment selection:

Disposal Distances and Transport. Disposal distances can impact the selection of the type of dredge and methodology for transporting the material to the designated disposal site. Typically, transport distances greater than 4-5 miles would generally be more suitable for barge transport. Distances less than that would be more suitable for hydraulic transport. The cost of additional pipeline boosters escalates the unit price of transportation by the addition of the equipment and the reduction in the effective running time of the dredging plant. Right-of-ways and easements may limit the use of pipelines for hydraulic disposal. In addition, floating pipelines in the river may impact both commercial and recreational navigation.

The project will be broken down into segments in which the dredging areas and corresponding volumes of sediment to be excavated will be optimally correlated to the nearest disposal area to minimize the transport costs. The individual dredging areas will be compared against barge transport and hydraulic transport to decide the more preferred method of transport for each area.

Upland Disposal Site Capacity. The capacity of the disposal site can limit the maximum effective production rate a dredge could maintain without exceeding the site's capacity.

The selected upland disposal site will be required to have sufficient capacity to handle the proposed volume of dredged material to be placed. The calculation for the capacity of the upland site will include the dredged material in situ volume (required dredging, allowable overdepth dredging, and excess dredging), dredged material bulking factor, excess water volume, and freeboard requirements. All these factors will vary depending upon the dredging methodology.

There are special considerations that need to be taken into account for hydraulic dredging, transport and placement at an upland disposal facility. Since hydraulic dredging produces a significant quantity of water as part of the dredge slurry, the configuration and capacity of the disposal site needs to be large enough to adequately handle the flow through rate of a hydraulic dredge and to provide sufficient detention time within the site for the dredged material to settle from the dredge slurry.

Should mechanical dredging be required, the dredged material would need to be offloaded from haul barges onto a staging area, where the dredged material may need to be dewatered prior to transport to the disposal site.

The upland disposal site capacity dictates whether the site can be used for active dewatering or passive dewatering. Other variables that impact the required size of a disposal site include the percentage of water content in the sediments at the time of placement, the physical characteristics of the material, the sediment settling time. The geotechnical properties of the site and the available acreage footprint of the disposal site must be considered in the design of the containment structures (dikes) for the disposal site. Water quality of the disposal site effluent can be increased by increasing the retention time for the dredged material slurry within disposal site by the use of multiple retention cells and interior berms if sufficient disposal site footprint is available.

Dredge equipment selection and disposal site selection are closely related and an iterative process. The parameters discussed above will be considered during the selection of dredge equipment and the design or selection of disposal site(s).

Water Management for Hydraulically Dredged Sediment. The hydraulic dredging process adds significant water volume to the dredged material. This water has to be removed from the dredged material at the disposal site either through active or passive dewatering or a combination of the two. Minimizing the transport water can reap substantial savings in treatment efforts in the dewatering and disposal sites. Passive dewatering allows the entrained water to decant from the slurry, while active dewatering uses mechanical means such as centrifuges, belt presses, or filter presses to remove water from the dredged slurry.

Passive dewatering requires larger disposal area footprints and longer dewatering times than required for active dewatering methods. Additional cell structures within the site and interior berms are often required to provide sufficient settling time for a passive dewatering system. Fine-grained sediment often forms a crust over the disposal area and traps the water within the site. Mechanical assistance, such as trenching and breaking up the crust, is often required to dewater the sediment.

An active dewatering system, however, can reduce the amount of entrained water within the retention site and only requires the additional acreage to house the dewatering system itself plus a reduced storage footprint for the dewatered sediment. The capacity of mechanical dewatering equipment is generally limited and large volumes of dredged material require multiple equipment set-ups.

The determination of the water handling requirements for a disposal site will be evaluated based upon the flow rate from the dredging operations, the number of available sites, the percentage of entrained water in the sediments, the desired water content of the dewatered sediment, and the footprint available for the dewatering system(s).

Additionally, once the water is decanted from the dredged material a means to return it to the river system is required and treatment of the decanted water prior to re-introduction into the river system may also be required. The treatment required will be determined based on water quality requirements for the project.

Some mechanical/hydraulic hybrid dredging technologies utilize a closed system to use water to transport the material to the dewatering/disposal site and then to return the transport water back to the dredge for re-use. Dredging processes will be evaluated to compare the impacts of treatment of transport water against the additional unit costs of a closed system with its lesser treatment requirements for transport water.

2.6.4.12 Accessibility of Equipment into Various Cleanup Areas

Access to water-related activities can be achieved by either direct transit on the river or by launching equipment from shore. Portable equipment would be necessary in some segments of the river where dams prevent travel between sections. Small hydraulic and mechanical dredges can be readily assembled and launched into the water. Access to the upland sites from the water would be required for pipeline right-of-ways and for equipment access, if landside access were prohibited.

Certain dredges are better suited to reach and excavate difficult locations. Special consideration may be required for certain locations such as under pier areas, slope dredging, dredging next to structures such as bridge piers, and dredging in areas with utility crossings, etc. Bridge clearance or overhead power lines may also pose accessibility issues.

2.6.5 Potential Environmental Impacts During Dredging and Best Management Practices

The dredge plan will be developed to minimize potential impacts to existing habitat, minimize potential impacts to water quality, reflect seasonal restrictions, and incorporate BMPs.

2.6.5.1 Habitat

The RI identifies little wetland, nearshore submerged aquatic vegetation, or in-water habitat in OU 3 (Retec, 2002c). In addition, no fish spawning areas were identified for OU 3. The RI also identifies little nearshore habitat within OU 4. However, small wetlands and submerged aquatic vegetation have been identified at the southern end of the reach. Spawning cribs have been installed by WDNR in the southern end and a considerable influx of fish enters OU 4 from Green Bay (Retec, 2002c). If acceptable to the Response Agencies, the dredge plan will be designed to avoid unnecessary impacts to these areas. Setbacks from these areas will be implemented in the design.

Should dredging be required in areas with identified habitat, mitigation may be required by the Response Agencies and will need to be determined in discussions with the Response Agencies.

2.6.5.2 Water Quality

The short-term impacts to water quality at the point of dredging, or for return flow effluent from hydraulic dredging, have not been assessed. The dredging elutriate test (DRET)is a standard test developed by USACE to assess potential water quality impacts at the point of dredging for mechanical dredges (DiGiano et al., 1995). Other elutriate tests, such as the modified elutriate test (MET) (Palermo, 1986) and standard elutriate test (USEPA and USACE, 1998), are also used for hydraulic dredging evaluation. Water quality impacts from potential return water from hydraulic dredging and transport to an upland disposal facility will also need to be evaluated. Typical testing includes performing the column settling test (CST) (USACE, 1987) to evaluate dredged material settling characteristics, disposal facility sizing and configuration, and effluent water quality assessment. Additional leachate testing may be necessary to predict long-term water quality impacts of dredged material placed in an upland facility.

Testing results provide input data that are typically used in computer models to help predict the potential for short-term and long-term water quality impacts. Point of dredging modeling typically includes running the DREDGE model (Hayes and Je, 2000). The SETTLE model (USACE, 1992) is a standard model used to evaluate the effectiveness of hydraulic dredging with upland disposal. Additional discussion of these data needs are presented in Section 3.1.

2.6.5.3 Seasonal Restrictions

Seasonal restrictions may include winter icing, low water levels in the summer, and winter storms resulting in high current velocities. These conditions may either slow dredging or halt it altogether.

Icing of the river can impede dredging efforts and can totally prevent access to certain areas; therefore, production can suffer. Additionally, upland disposal sites and dewatering activities can incur icing of the water surfaces, freezing of mechanical components, and result in ineffective operation of water treatment and decanting operations. The work window is envisioned for 35 weeks from April to November to avoid the icing impacts.

Impacts from high volume flow discharges related to storm events can disrupt dredging production. Operational procedures will be formulated to adjust for any large flow fluctuations and to secure any completed activities from damage or erosion of exposed contaminants. The number of active, uncompleted dredging reaches will be limited so as to reduce the risks of any scouring impacts. Similarly, low flows during the summer can slow production and operational procedures will be developed to account for reduced water depths.

Time, production impacts, winterizing efforts and the resultant cost impacts will be estimated for the seasonal work period inhibiting factors. Quality control procedures will be instituted that will recognize the potential impacts from icing and potential heavy flow discharges and will delineate risk reduction measures.

2.6.5.4 Best Management Practices

After evaluating potential environmental impacts, BMPs will be identified to assess feasibility and effectiveness of specifying BMPs for dredging operations to minimize potential impacts. BMPs may include operational controls, institutional controls, and/or use of specialized equipment.

2.6.6 Post-Dredge Residual Management

Residual contamination is typically monitored in surface sediments following the completion of remedial dredging activities. Residual contaminants are inevitable when dredging contaminated sediments due to the inability of any dredging equipment to completely remove all sediment within a dredge prism. Resuspension of sediment during bucket impact and retrieval, or disturbance during hydraulic excavation, results in fine-grained sediment becoming suspended and transported away from the immediate location of the dredge. Larger grain sizes, such as sand, settle out of the water column fairly rapidly while finer-grained sediment, such as silts and clays, can remain in suspension and travel long distances before settling. Two management approaches will be implemented to address this potential residual contamination:

1. Specifying appropriate BMPs during dredging to limit residual contamination sources during dredging operations.
2. Employing methodologies to address residual contamination after the completion of dredging.

BMP controls will be developed as part of the remedial design specifications to minimize to the extent practical the magnitude of residual contamination. These controls may include the use of a precise horizontal and vertical positioning system and real-time monitoring of the dredge head and bed elevation. Controlling vessel draft and movement will be addressed in the specifications to limit the transport of contaminated sediment via vessel propeller wash scour. In addition, the design will calculate the thickness of cut that will reduce the impact of a cut slope sloughing back into the completed dredge cut.

If post-dredging residual contamination levels exceed the ROD-specified SWAC, additional dredging may be implemented to remove the remaining contamination to achieve the SWAC. The ROD also provides for the placement of a sand cover on dredged areas to reduce the surficial concentrations such that the SWAC is achieved.

2.7 Pre-Design Transport and Disposal Evaluation

This section presents a status of work completed to date by WDNR on the development of transport and disposal plans for Lower Fox River sediment from OUs 3, 4 and 5. Securing implementable and cost-effective transport and disposal options will be critical components of the remedial action work for OUs 3, 4 and 5.

The FS (Retec, 2002b) for the Lower Fox River evaluated a range of disposal options including landfill disposal (whether existing, proposed or a new dedicated landfill), confined aquatic disposal (CAD), and confined disposal facility (CDF). For sediment projects, a land-based facility that serves as both a dewatering basin and a NR 500 landfill is often described as a CDF. The ROD for OUs 3, 4, and 5 selected the new, dedicated CDF option with the dredge slurry transported via a pipeline to a site within Brown County. The *Detailed Evaluation of Alternatives (DEA) Report* (Retec, 2003) supported the general effectiveness of a CDF-type facility. Beneficial reuse options also exist for sediments containing low or acceptable levels of PCBs.

2.7.1 Initial Inventory of Potential Disposal Facilities

There are approximately 15 private and municipal landfills within a 60-mile radius of Fox RM 3.5 (a midpoint between the De Pere Dam and the mouth of the Fox River at Green bay) that have remaining capacities or design capacities greater than 500,000 cy. Two of those landfills have already accepted PCB contaminated sediments from the Fox River demonstration projects (Fort James Green Bay-West facility for SMU 56/57 and the Winnebago Sunnyview Landfill for Deposit N.). In addition, other area landfills may have or could obtain the necessary approvals to accept PCB contaminated sediments.

With regards to larger capacity there are several area landfills that have approximately 3 million cy or more of capacity remaining as of January 2003. In addition, a 7 million-cy expansion is currently under consideration by WDNR at one of these sites.

Important information to consider in the analysis of a particular disposal option(s), are the development stage of a facility, ownership, design capacity and remaining capacity. In addition, the general locations of the disposal options are important since there are cost impacts related to transport technique (e.g., truck, pipeline, rail, etc.).

A methodology for an initial screening or evaluation of disposal options is presented in Section 3.2 of this Work Plan. Factors that may be considered include:

- Current development stage of the facility;
- Ownership;
- Design capacity;
- Remaining capacity;
- Location of the facility and distance from dredging;
- Social and political climate;
- Implementability; and
- Cost.

2.7.1.1 Disposal of TSCA-Regulated Material

Based on historical sediment data, in situ PCB concentrations in some areas of OU 4 are equal to or above 50 ppm and may become subject to Toxic Substances Control Act (TSCA)-imposed management and disposal requirements. The Wayne Disposal Facility in Belleville, Michigan is the sole disposal facility located in USEPA Region 5 that is authorized to accept waste containing 50 ppm or greater concentrations of PCBs (commonly referred to as "TSCA-regulated material"). During the remedial design, an analysis will be conducted on the volume of TSCA-regulated material, if any, which may need to be disposed of in a TSCA licensed facility. That disposal amount, if any, will depend on factors such as whether the TSCA determination is made based on post-sediment processing and whether any Wisconsin landfills will be authorized to accept TSCA-regulated material. In 1995, USEPA granted WDNR approval to allow certain Wisconsin landfills to accept sediments containing 50 ppm or greater PCBs. USEPA's approval expired in 2000. WDNR and USEPA are currently considering a similar approval process, which would allow TSCA-regulated material to be disposed of at certain Wisconsin landfills.

2.7.1.2 Undeveloped Landfills

In addition to the existing landfill capacity space that is available within this region the opportunity always exists to evaluate the siting, permitting and constructing a new facility. The process for gaining approval of a new landfill can take several years to complete.

Undeveloped sites can also include locations where preliminary landfill siting and engineering work has been conducted to some extent during a previous landfill siting evaluation. Often the information from such a preliminary siting evaluation are available and could be used to possibly shorten the time span to locate, permit and construct a new facility.

2.7.1.3 Other Existing Options

Beneficial reuse of low level PCB contaminated sediments could occur if a proper demonstration shows that the beneficial reuse option is protective to human health and the environment. Examples of potential beneficial reuses include landfill cover, habitat creation, beach nourishment and construction fill.

2.7.2 Dewatering, Material Handling, and Water Treatment Considerations

Interdependence exists in the selection, evaluation and design of the dewatering, transport and water treatment components of a sediment removal project. In addition, selection of these components is also heavily dependent on the volume of sediment to be removed and the type of dredge conducting the removal. As such, while these components are often addressed individually, as they will be in this section of the RD Work Plan, during the remedial design the interdependence of these technologies will clearly be recognized and considered in the design.

2.7.2.1 Dewatering

Hydraulic dredging requires the development of a dewatering method for separating the dredge solids from the carriage water. The two general dewatering methods available include passive and mechanical dewatering. Passive dewatering typically entails hydraulic transport of the dredge slurry to a settling basin (e.g., NR 500 designed facility) and then the settling of the solids over time. In this type of dewatering facility the dewatered sediments could remain in the basin and be closed in-place or could be transferred to an adjacent cell(s) for closure. Mechanical dewatering of the dredge slurry can consist of hydrocyclones, centrifugation, filter presses, and belt presses. In addition drying agents can be added to the sediment to also facilitate the formation of dewatered sediment that is suitable for transport and disposal.

Mechanical dredges are often able to remove the sediment at in situ densities and thus do not require the same level of dewatering effort which accompanies hydraulic dredging. It still may be necessary, however, to amend or further dry the sediment for transport and disposal purposes.

The two demonstration projects on the Lower Fox River utilized hydraulic dredging, with pipeline transport of the slurry to shore and mechanical dewatering using filter presses. While this process was effective for the demonstration projects, the current scale of work proposed for OUs 2, 3, 4 and 5 requires a complete new evaluation of an appropriate design. In addition, the dewatering endpoint for both projects was based on an acceptable landfill strength requirement (0.4 tons per square foot). Given a different landfill design it is possible that a new strength requirement and thus sediment dewatering endpoint could be developed for the proposed work in OUs 2, 3, 4 and 5.

The ROD-selected remedy is hydraulic dredging with hydraulic transport of the slurry a maximum distance of 18 miles to a facility in southern Brown County (WDNR and USEPA, 2003). Under this plan the dredge slurry would be discharged into a series of passive dewatering basins and ultimately disposed of in an adjacent or nearby monofill.

As previously stated the selection of the actual dewatering process of sediments will be dependent upon the sediment volume to be removed, the characteristics of the sediment, consistency of slurry (water to solids ratio), the type of dredge utilized for the project, available transport routes, available disposal options and the dewatering requirements of any disposal facility. The proposed or baseline process identified in the ROD can be used to help assist in the actual design; however, the design level effort proposed for this project will quantitatively address the components and interdependence of the components such that a new design process could emerge.

2.7.2.2 Transport

The selection of transport for the dewatered sediment or sediment slurry will also be dependent on the individual remedial action components (sediment volume, dredge type, dewatering method, disposal facility, etc) and the overall remedial action. In addition the transport method selected needs to be compatible with the characteristics of the river, the staging area, local infrastructure conditions and river commerce and transportation. Transport options include truck, rail, barge, and pipeline. All of these methods have been used in the transport of contaminated sediments at various projects across the county.

The two demonstration projects on the Lower Fox River utilized truck transport of the dewatered sediment to the approved disposal locations. Since the dewatering endpoint for these projects was a stringent landfill strength requirement the dewatered sediment readily passed the paint filter test. Transportation routes and contingency procedures were developed with local government units and agency input.

The ROD-selected remedy includes pipeline transport of a dredge slurry to a passive dewatering facility (CDF-like facility) in southern Brown County (WDNR and USEPA, 2003). An overland route for this pipeline was preliminary proposed in the ROD which would follow existing roads or corridors. Any overland route of this type for a dredge slurry pipeline would likely require access agreements to cross private property and also would need to obtain construction approvals from local government units.

Proper design and engineering of this pipeline or any other transport method for a dredge slurry or dewatered sediment will be conducted during the remedial design. Specific considerations for pipeline transport include pipe materials, booster pumps, cleanout points, slurry flow rate, cost, schedule, and compatibility with the dredge removal rate. General design complements for any transport method will include compatibility with the overall sediment removal, dewatering and disposal processes, schedule, cost, permitting, safety and welfare of the general public, and local approvals.

2.7.2.3 Water Treatment

Depending on the quality of sediment elutriates, carriage water from the sediment removal operation may require treatment prior to discharging back to the Lower Fox River. In addition to the carriage water, certain precipitation runoff water, equipment wash water, and possibly landfill decant water and leachate may also require treatment. General water treatment methods include clarification, filtration, and granular activated carbon.

The two demonstration projects on the Lower Fox River utilized standard water treatment technologies of clarification, filtration, and carbon adsorption. The projects were able to comply with discharge requirements set forth in the WPDES permits.

During the water treatment design, the sequence, combination, and sizing of the equipment will be dependent on water quality of the sediment elutriate/carriage water, sediment removal volume, dredge method, dewatering methods, and the type and location of the disposal facility.

2.7.3 Potential Permitting and Approval Considerations (Disposal Facilities)

Under Wisconsin law, the design, operation, maintenance and closure is governed not only by state regulatory and permitting requirements, but also by formal agreements between landfill owners, the host community and nearby, impacted local governments. The Wisconsin landfill permitting process is well defined and has been used many times in the state to site, permit, construct, operate, and close landfills. The formal agreements between the landfill owner and host community are commonly referred to as "Local Agreements". These agreements typically address, among other things, the types of wastes and operational considerations at the landfill. Potential permitting and approval considerations associated with design of the cleanup remedy are discussed further in Section 4.

2.8 Pre-Design Monitored Natural Recovery Evaluation

The Records of Decision issued by the WDNR and USEPA (2002, 2003) provide for Monitored Natural Recovery (MNR) as the preferred remedial alternative in the following areas:

- OU 2 (Appleton to Little Rapids, excluding Deposit DD)
- OU 5 (Green Bay)

As set forth in the RODs, the implementation of MNR in the Fox River and Green Bay would include the following components:

- Surface sediment performance monitoring following completion of remedial actions;
- Long-term verification monitoring of surface sediment (in MNR areas), water, and fish tissue to measure progress toward and achievement of RAOs;
- Institutional controls, as needed, to restrict access or use of the Site during the recovery period. Institutional controls would primarily consist of fish consumption advisories and fishing restrictions. In addition, site access restrictions or land and water use restrictions may be considered.
- Additional evaluation, as needed, of contaminant distributions, risks, fate and transport processes, and recovery times.

2.8.1 Natural Recovery Objectives

Following the planned remediation in the Lower Fox River, MNR would then be implemented to effect further site-wide reduction of PCB residues in sediments, water, and fish tissue in order to meet long-term RAOs. Because RAOs will not be immediately achieved at the conclusion of the remedial action, some degree of MNR may be necessary in all parts of the Fox River and Green Bay.

The goal of the active remediation program is to remediate sediment that exceeds the RAL of 1 ppm PCBs. Remediation is expected to result in a SWAC at or below 0.26 ppm PCBs in OU 3 and 0.25 ppm PCBs in OU 4. If, at the end of the remedial action, neither the RAL (1 ppm PCB) nor the appropriate SWACs have been achieved in these areas, then the Response Agencies will determine an appropriate response option. Such response options may include:

- Additional dredging;
- Capping;
- Additional backfill; and/or
- Management of dredging residuals through natural attenuation processes, as appropriate.

2.8.1.1 Natural Recovery Time Frames

WDNR and USEPA established the following time frames for achievement of RAOs following completion of the remedial action:

- Recreational Anglers, Unrestricted Fish Consumption – 10 years
- High-Intake Consumers, Unrestricted Fish Consumption – 30 years
- Protection of Fish-Eating Birds and Mammals – 30 years

2.8.2 Natural Recovery Processes

A number of processes have and will contribute to the natural recovery of sediments in the Lower Fox River and Green Bay. Some of the primary processes include sedimentation and burial, dispersion, desorption and diffusion, and biodegradation. The relative importance of one process versus another will depend on a number of site-specific conditions that vary from place to place.

2.8.2.1 Sedimentation

In depositional areas, burial of contaminants with a cover of clean overlying sediment is an important natural recovery process. Burial removes PCBs from direct contact with aquatic life in the river and bay.

Radioisotope dating of sediment cores indicate that certain areas of the Lower Fox River are depositional, whereas other areas are not consistently depositional. In nondepositional areas, dispersion and diffusion/dissolution are likely the more important natural recovery processes (see below). Net sedimentation rates in the Lower Fox River have ranged from < 0.5 to 2.5 cm/yr (LTI, 2002c). Navigational dredging has artificially disturbed sedimentation rates in parts of OU 4 and 5. However, even in these areas, the radioisotope data indicate that such sediments remain net depositional in nature over the long term (i.e., decadal time scales).

2.8.2.2 Dispersion

Dispersion is a physical mixing process whereby existing PCB residues in ambient sediments are mixed with new sediments entering the river system. Dispersion occurs when ambient sediments are resuspended and mixed with suspended sediments in transport in the river. When the suspended sediments are redeposited downstream, they represent a mixture of new and relict material.

Dispersion is expected to be an important natural recovery process and will effect an overall reduction of average PCB concentrations in surface sediments, and thus, a reduction in site risk associated with both bioaccumulation and direct contact.

2.8.2.3 Desorption, Diffusion, and Dissolution

Desorption and diffusion are chemical processes whereby PCBs partition off the sediments and are released to pore waters or directly to the overlying water column. Desorption may occur in situ in the sediments causing PCBs to diffuse upward through the sediment column via pore waters, and discharge to the river. Desorption may also occur in the water column, when some of the PCB burden on sediments is stripped off during resuspension events. Once PCBs are solubilized in the water column, they are available for volatilization and photochemical degradation, which results in permanent destruction and removal of PCB mass from the system.

2.8.2.4 Biodegradation

Biodegradation of PCBs is a complex process that involves different mechanisms under aerobic and anaerobic conditions, and preferences for different microbes to attack certain PCB homologs (i.e., degree of chlorine substitution) and congeners (i.e., location of chlorine substitution on the biphenyl molecule).

Previous studies of PCB biodegradation in the Fox River and Green Bay have reported limited evidence for anaerobic dechlorination or aerobic decomposition (McLaughlin, 1994; BBL, 1993; Pham, 1993). However, evidence for both aerobic and anaerobic PCB degradation processes have been reported elsewhere in numerous laboratory and field studies (Sonzogni et al., 1991; Minkley et al., 1999; Sokol et al., 1998; others as referenced in Retec 2002c).

2.8.3 PCB Source Load Reductions

Natural recovery is contingent on control of PCB source loads. Historical source control actions have already resulted in measurable reductions in sediment PCB concentrations.

2.8.3.1 Historical Load Reductions

PCB concentrations in the Lower Fox River and Green Bay have recovered to date in response to environmental controls that have been implemented in the basin since at least the 1970s. Foremost among these controls was curtailment of PCB discharges to the river beginning in 1971. This has resulted in significant reductions in surface sediment and fish tissue concentrations over time.

WDNR has estimated that 313,600 kg of PCBs were released to the river system between 1954 and 1971 (WDNR, 1999a). This should be regarded as a minimum estimate as other undocumented historical sources of PCBs to the river system undoubtedly existed. The current estimate of residual PCB mass in the Fox River and Green Bay is 99,826 kg. At a minimum, there has been a 68 percent reduction in the resident PCB mass since PCB discharge controls were implemented 30 years ago. To the extent there were additional historical PCB loads to the river, and the total load has been underestimated, even greater reductions have been realized.

2.9 Contingent Capping Remedy Evaluation

Both RODs for the Site identify in situ capping as a "contingent remedy that may supplement the selected remedy in certain circumstances". The ROD for OUs 3-5 (WDNR and USEPA, 2003) confirms that "capping is considered a viable and protective alternative…and may be implemented" if certain criteria specified by ROD Sections 13.4-13.6 can be met. Finally, the RODs direct that "[t]he specific areas where caps could be placed will be determined during design" and that "[c]ap construction specifications would be determined during design."

The SOW reiterates that "[c]apping of certain areas…may be proposed during design and will be given consideration by the Response Agencies, consistent with the requirements of the ROD for selection of the contingent remedy. The SOW also indicates that "[i]f Respondents, consistent with the ROD capping contingency, propose capping any area as part of the final remedy, Respondents shall provide a detailed submittal with technical justification supporting such a [capping] proposal to the Response Agencies for approval."

Design considerations relating to the contingent capping remedy are discussed in detail in Appendix B to this Work Plan.

3 PRE-DESIGN DATA COLLECTION

This section of the RD Work Plan provides a summary of remedial design data gaps identified from the review of existing data, as presented in Section 2. The discussion is organized as follows:

- Section 3.1 – Dredge Design Data Gaps
- Section 3.2 – Dewatering, Transport, and Disposal Site Design Data Gaps
- Section 3.3 – Contingent Capping Remedy Data Gaps
- Section 3.4 – Baseline Monitoring and Natural Recovery Data Gaps

A Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP) (Shaw and Anchor, 2004a) are being written under separate cover and will be implemented during the summer 2004 sampling and analysis program to address these identified data gaps.

3.1 Dredge Design Data Gaps

Completing the dredge plan and selecting equipment requires using multiple types of data as discussed in Section 2.6. The following sections define additional data required to design a dredging remedy for the site. The SAP provides the proposed additional details regarding sediment sampling equipment, sampling density, collection methods, and analytical methods (Shaw and Anchor, 2004a).

3.1.1 Dredge Plan Data Requirements

The data required to develop DMUs and design the dredge prism include:

- Extent of PCB concentrations relative to ROD-specific RALs (chemistry data in combination with surrogate data; e.g., sub-bottom profiles and/or poling data, as appropriate);
- Locations of infrastructure, debris, and obstructions;
- Configuration and location of the federally authorized and actively maintained navigation channel;
- Bathymetry; and
- Site geotechnical properties (e.g., moisture content, grain size distribution, Atterberg limits, bulk density, relative density).

3.1.1.1 Extent of PCB Concentrations

The key information required to develop the dredge plan is a detailed characterization of the vertical and horizontal extent of PCB concentrations relative to the ROD-specified RAL of 1 ppm. Historical PCB data (Section 2.3) provide a general characterization of the nature and extent of PCBs within the site, but are not sufficient for remedial design purposes. The specific data required for development of the dredge plan are outlined below:

Spatial Extent of PCB Concentrations. To assist in the delineation of the remediation boundaries, the site will be divided into four general areas for characterization purposes. Two of the four general categories ("A" and "C" areas as described below) will be established to better define critical dredge prism boundaries (i.e., areas with sediment exceeding the TSCA 50 ppm PCB criterion and areas close to the 1-ppm RAL, respectively). These more critical areas will receive a higher coring density during the sampling program. The remaining two categories ("B" and "D" areas) consist of sediments for which prior site characterization data are sufficient to generally delineate areas greater than or less than the RAL, allowing a more moderate coring density for the purpose of dredge plan design.

The grid spacings associated with moderate- and high-density sampling areas are based on the results of geostatistical analysis (spatial correlation structure and lognormal kriging) of the existing site characterization data, as discussed later in this section. Further details of the spatial correlation analysis are provided in Appendix A. To further assist in interpolating the remediation boundary between cores, poling data and/or sub-bottom profiling data may be considered as appropriate. The four characterization areas are delineated using kriged predictions of maximum PCB concentrations. The four areas are defined as follows:

- **Category "A"** – Refined delineation of the area(s) and depths of sediment that may contain greater than 50-ppm total PCBs is needed for remedial design, since such sediments may require special considerations (e.g., contingent capping remedy not allowed; disposal in an NR 500 landfill). To account for statistical uncertainty, Category "A" designation has been assigned to all areas with and estimated (kriged) concentration of 10 ppm or above. Allowing for uncertainty in the kriged predictions, areas with predicted PCB concentrations greater than 10 ppm are included in this category (approximately equal to the TSCA criterion minus the kriging standard error). The target sediment core sampling density in

Category "A" areas is an asymmetrical grid on 165-foot (transverse) by 410-foot (longitudinal) centers (i.e., one core per 1.6 acres).

- **Category "B"** – This category refers to those areas currently characterized by a high probability that PCB concentrations either at the surface or at depth exceed 1 ppm, and will therefore require remediation, but are not likely to exceed the TSCA criterion of 50 ppm (defined as areas with estimated maximum PCB concentrations between 2 and 10 ppm). The key remedial design data requirement is related to the vertical extent of sediments exceeding the RAL. The uniformity of sediment stratigraphy in these areas will be confirmed by analysis of existing sub-bottom profiling and/or poling data. In Category "B" areas, characterization-level core sampling on 330-foot (transverse) by 820-foot (longitudinal) centers (i.e., one core per 6.2 acres) will be collected.
- **Category "C" –** Category "C" areas occur near the horizontal dredge prism boundary, and are currently characterized by uncertainty as to whether surface or subsurface PCB concentrations exceed 1 ppm (defined as areas with estimated maximum PCB concentrations ranging from 0.5 to 2 ppm). These areas will be sampled at a higher-density spacing on 165-foot (transverse) by 410-foot (longitudinal) grid intervals (i.e., one core per 1.6 acres) to more precisely define this boundary.
- **Category "D"** – Category "D" areas exhibit a low probability that PCB concentrations either at the surface or at depth exceed 1 ppm (defined as areas with estimated maximum PCB concentrations that are consistently below 0.5 ppm). These areas will be sampled at a moderate density for verification purposes, i.e., core sampling on 330-foot (transverse) by 820-foot (longitudinal) centers (one core per 6.2 acres).

Vertical Extent of PCB Concentrations. Sediment cores will be advanced to the depth of refusal or to the practical limits of the vibrocoring equipment to ensure that the depth of contamination is fully defined; the depth of refusal will be estimated by taking a poling measurement on station prior to deploying the corer. The maximum thickness of sediments exceeding the 1-ppm RAL was previously estimated by WDNR using an IDW interpolation scheme, as described in Technical Memorandum 2e (WDNR, 1999b) and shown on Figure 2-10. To support this Work Plan, an alternative estimate of sediments exceeding the 1-ppm RAL was developed using "depth of contamination" as an index parameter, as shown on Figure 2-11 (see Section 2.3.3.2). This revised estimate of the depth of the PCB boundary will be used to select specific core intervals for chemical analysis; however, all core intervals will be archived in case deeper or shallower analysis is needed to define the boundary.

All cores will be subsampled in 6-inch intervals. In addition, the uppermost surface sediment interval (top 4 inches, or 10 cm) will be collected using a van Veen sampler, in part to support calculation of the SWAC. The interval containing the projected depth of the RAL (i.e., the projected base of the dredge prism) will be submitted for chemical analysis of PCBs, as well as the two intervals above and below the target interval (i.e., plus or minus 1 foot). The remaining samples will be archived (frozen) for possible future analysis pending initial results. Archived samples will be analyzed in a second phase of testing if needed to define the vertical RAL boundary.

In prospective TSCA (Category "A") areas, representative intervals will be analyzed from the full length of the cores. In areas where the contingent capping remedy will be evaluated, it will also be necessary to analyze representative samples from the full length of the cores to support groundwater fate and transport evaluations. In these areas where full definition of the PCB profile is required, samples will be analyzed on one-foot intervals (i.e., every other 6-inch sample will be submitted for analysis). The intervening samples will be archived and may be submitted in a second phase of analysis, if necessary, to further delineate sediments above the TSCA criterion or to refine the profile definition in potential contingent capping areas.

Grid Spacing and Spatial Correlation Analysis. The sample grid spacing in OUs 2–5 is based on the following considerations:

- Spatial correlation scales determined through geostatistical analysis of surface and subsurface sediments; and
- Qualitative analysis of surrogate information (sub-bottom profiles and/or poling data) to identify areas of complex structure in the underlying native surface. As generally depicted in Figures 2-13 and 2-14, surrogate information will be used to help map the 1-ppm vertical interface between core locations for the purpose of dredge plan design.

Spatial correlation scales were determined through semivariogram analysis using standard geostatistical techniques (e.g., Isaaks and Srivastava, 1989). Semivariograms were evaluated in OU 3 and OU 4 for both surface and subsurface data. Subsurface semivariograms were based on maximum PCB concentrations in each core profile. The analysis was performed using logarithms of the concentration data to help normalize the distribution.

Semivariograms developed using data from the southern (unmaintained) half of OU 4 (i.e., OU 4A; SMUs 20 through 60) showed the most well defined structure because this area is characterized by the highest sampling density and has not been artificially disturbed by dredging for many years. The correlation structures in this well studied reach of the Lower Fox River are generally consistent with results from OU 3 and OU 4B (although data are more sparse in these areas) and were used to determine an appropriate grid spacing for delineating the RAL boundary. Semivariograms of surface sediments in SMUs 20 to 60, surface sediments in SMUs 26 to 60 (i.e., excluding the somewhat anomalous gravel/cobble area just below De Pere Dam; Figure 2-8), and subsurface sediments in SMUs 20 to 60 are presented on Figure 3-1. The semivariograms were fitted with spherical and/or exponential correlation models; they show a pronounced asymmetry, such that longitudinal (along-channel) correlation scales are approximately three times larger than transverse (cross-channel) correlation scales.

A summary of correlation scales in the unmaintained section of OU 4 is provided in the table below.

Location	95% Range Transverse (meters)	95% Range Longitudinal (meters)	100% Range Transverse (meters)	100% Range Longitudinal (meters)
SMU 20-60 Surface	270	400	350	1,000
SMU 26-60 Surface	160	600	200	900
SMU 20 to 60 Subsurface	125	400	150	670

Based on the semivariogram analysis, a reasonable average correlation scale for OU 3 and OU 4 is 200 m (660 ft) in the transverse direction, and 500 meters (1,640 ft) in the longitudinal direction. Sample grids based on one-half the distance of the correlation scale is appropriate (Caeiro et al., 2003) and will be applied to Category B and D areas. A higher density sampling grid, based on one-quarter the distance of the correlation scale will be applied to Category A and C areas, where careful delineation of the 1-ppm RAL and 50 ppm TSCA criterion are required. Sample grid spacings are summarized in the table below.

Location	Transverse Range (meters)	Longitudinal Range (meters)	Transverse Range (feet)	Longitudinal Range (feet)	Area per Core (acres)
Average Correlation Scale	200	500	660	1,640	N/A
Grid Spacing – Category B & D	100	250	330	820	6.2
Grid Spacing – Category A & C	50	125	165	410	1.6

In addition to determining grid spacings that will ensure good inter-sample correlation, grid spacings may be locally adjusted based on a qualitative review of the recently collected sub-bottom profiling data, if and when it is available, or the poling measurements which are scheduled to be collected prior to coring (see Poling SAP; Shaw and Anchor, 2004b). If areas of complex sub-bottom structures are observed which may influence PCB accumulations in the overlying sediment, additional cores may be added to characterize these complex areas. On the other hand, grid spacings may be expanded in areas of relatively uniform and horizontal stratigraphy.

3.1.1.2 Location of Infrastructure, Debris, and Obstructions

The location of infrastructure, debris, and obstructions is critical to developing a constructible dredge plan design. Identifying significant debris areas is also important to help select appropriate equipment. Accurate delineation of these areas will aid in (1) identifying required setbacks to avoid potential impacts to infrastructure and to avoid utilities and obstructions, and (2) developing debris removal and/or avoidance plans to minimize construction-related water quality and dredge residual impacts.

Other reports (e.g., Retec et al., 2003b) have used NOAA Chart 14918, WDNR, and Brown County information to identify infrastructure and obstructions. This information, as discussed in Section 2.2.5 and shown in Figure 2-1, provides valuable infrastructure location information that requires verification. In addition, site surveys and literature research are needed to identify infrastructure and obstructions that are not included as part of the existing data.

Verification of existing data and identification of new information will be conducted using the following resources:

- Recent aerial photographs were collected by Retec in late 2003. These photographs extend several hundred feet landward of the shoreline, generally up to the nearest public road (Retec et al., 2003b). These photographs will be used to verify existing upland infrastructure. These data were recently provided by WDNR, and it is assumed the data are sufficient for design-level analysis. However, if data are not sufficient, then the collection of additional data may be necessary for the completion of the design.
- Side-scan sonar data collected by Retec in late 2003 (Retec et al., 2003b) using a high resolution, single frequency system will be used to verify known obstructions, debris, and underwater utilities located above the mudline, and to identify any new objects that may exist that could cause an impediment to dredging operations. These data were recently provided by WDNR, and it is assumed the data are sufficient for design-level analysis. However, if data are not sufficient, then the collection of additional data may be necessary for the completion of the design.
- Retec collected sub-bottom data in late 2003 using a multi-frequency chirp system (Retec et al., 2003b). These data will be evaluated to assist in verifying known submerged obstructions, debris, or utilities, if feasible. The utility of these data may be limited due to the existence of methane accumulations that can attenuate the acoustic signal and/or limit the ability to determine accurate depths to subsurface features.
- Coordination with local public utilities will be conducted to identify the locations and elevations of active and inactive utilities that cross the river, utility pipes that are located along the shoreline (e.g., water intakes pipes and stormwater discharge pipes), and buried structures that may be at various locations throughout the river.
- Infrastructure as-built drawings may be acquired to identify the locations and dimensions of subsurface infrastructure (e.g., bridge piers, footings, piles).
- Additional field verification of infrastructure locations and extents may be necessary contingent upon the outcome of the above research and data review (i.e., investigate ambiguous areas).

3.1.1.3 Federal Navigation Channel Interests

An important element of remedial design in the Lower Fox River will be the appropriate integration of cleanup with navigation maintenance dredging and other activities s such as ecosystem restoration and environmental dredging. As discussed in Section 2.2.4.3, between 1990 and 2002 an average of approximately 103,000 cy/year of sediments have been removed from OU 4B (along with a similar volume from Green Bay) to maintain the federal navigation channel under existing authorities of the USACE. The dredged sediments have been disposed through local sponsor agreements at regional CDFs, which have been approved for handling of navigational dredge material from the Lower Fox River and Green Bay. Maintenance dredging of the federal navigation channel in OU 4B is expected to continue into the foreseeable future.

During remedial design, federal navigation channel maintenance plans will be reviewed to identify the potential for cooperative efforts between the cleanup and USACE programs. Future navigation and WRDA dredging authorities in the Lower Fox River are currently being evaluated by USACE and the local sponsor (WDNR) as part of a General Investigations Feasibility Study of the Lower Fox River, that includes Environmental Dredging (WRDA Section 312) as well as other authorities such as navigation dredging (including advance maintenance) and ecosystem restoration. Certain work efforts such as data collection and analysis of the OU 4B navigation channel may be appropriately integrated in such a cooperative effort. As discussed in Sections 4 and 5 of this RD work plan, coordination between the cleanup and USACE/WRDA efforts will continue throughout remedial design.

3.1.1.4 Bathymetry

Recent bathymetric data are important for developing accurate dredge prism dimensions and calculating dredge volumes. Data collected through the USEPA FIELDS program in October/November 2002 were used to develop this RD work plan (Section 2.6.2.5 and Figure 2-4).

Retec will be collecting bathymetric data during summer 2004, with results expected to be available by fall (Section 5). The bathymetric survey will include the use of a multiple transducer, single-beam sweep system that can collect data over a 35-foot swath, ultimately resulting in a 3-foot by 5-foot data point grid. A higher resolution, multi-beam bathymetric survey may be conducted over features demonstrating high relief or extreme bed elevation change. This secondary bathymetric survey is dependent on the results of the single-beam survey (Retec et al., 2003b).

Based on a review of the SAP (Retec et al., 2003b), the 2004 bathymetric survey data should be adequate to support remedial design and will replace the USEPA FIELDS data. We understand that the bathymetry data will be merged with upland topographic data. It is possible that a gap of information may be identified between the bathymetry data and upland topographic data (i.e., the bathymetry survey may not reach the water's edge). This potential issue is currently being investigated, and may require a focused supplemental survey to support remedial design.

3.1.1.5 Site Geotechnical Properties

Knowledge of the geotechnical properties of the site is important for the development of slope setbacks and assessing material dredgeability as discussed in Section 2.6.2.6. Multiple investigations have collected various geotechnical samples (Sections 2.2.3.3 and 2.2.3.4); however, additional samples are necessary to support remedial design.

Side Slope Angle Setbacks. Design of the dredging remedy will involve selection of slope angles at which stable dredge cuts can be achieved and appropriate setback distances to accommodate existing structures or conditions. This will require evaluation of slope stability using accurate bathymetric data and geotechnical parameters measured in situ and ex situ from samples collected within and adjacent to the proposed dredge prism. Stability analyses will be necessary for typical slopes within each OU as well as for specific locations where unique conditions are present. These unique locations may include currently over-steepened areas and locations where existing structures (either upland or in-water) lie immediately adjacent to a proposed dredge cut.

Slope stability evaluation for these areas will require location-specific topography and bathymetric information as well as geotechnical data obtained from borings drilled using hollow-stem auger methods. Bathymetric surveys performed to date have utilized single-beam technology and collected data on tracklines perpendicular to the river, leaving portions of the river unmapped. However, complete coverage surveys, utilizing multi-beam techniques or single beam sweep arrays, will be required for remedial design. As discussed in Section 3.1.1.4, Retec is planning to conduct a complete coverage survey as a separate phase of work from that discussed herein. It is anticipated that the Retec survey will satisfy the bathymetric needs for design-level slope analysis. However, if the Retec survey does not satisfy those data needs, then the collection of additional data may performed as part of this work.

As discussed in Section 2.6.2.6 and in the accompanying SAP, deep borings (approximately 30 to 65 feet deep below sediment surface) will be drilled at select locations along the river banks to inform remedial design (Shaw and Anchor, 2004a). Relative soil density will be measured in the borings using SPT methods. Disturbed samples for advanced geotechnical testing will be collected at regular intervals with depth using a split-spoon sampler. Water elevation, soil description/classification, and other relevant subsurface conditions will be recorded during the investigations. Advanced geotechnical testing of select samples from the deep borings will include:

- Grain size;
- Atterberg limits
- Moisture content; and
- Triaxial compression (where appropriate);

Dredgeability. Geotechnical analysis will be conducted on select samples obtained from cores collected within the proposed dredged prisms. This testing will supplement the previously collected data as described in Section 2.2 to aid in the design of the dredging, handling, transport, dewatering, and disposal of contaminated sediment (see Section 3.2 for further discussion on handling, transport and dewatering). The geotechnical data will also provide more accurate measurement of the mass of solids, and therefore the mass of PCBs, present within the remedial area.

Geotechnical analyses to support the removal remedy design will likely include the following:

- Grain size (including hydrometer);
- Atterberg limits;
- Bulk density;
- Organic content;
- Specific gravity; and
- Percent solids (and/or moisture content).

The physical properties of the sediment measured in support of the dredging remedy will also provide a portion of the necessary data to properly design the contingent in situ capping remedy as described in Section 3.3.

3.1.2 Equipment Selection Data Requirements

The selection of appropriate equipment to perform the remedy also relies upon multiple types of data and information. Equipment selection will depend on the following information:

- Industry dredging capabilities and equipment types,
- Commercial and recreational vessel traffic,
- Bathymetry,
- Currents,
- Presence of significant debris and dredgeability of dredge material,
- Transport, dewatering, and disposal considerations,
- Accessibility of equipment into cleanup areas and to disposal areas,
- Potential short-term water quality impacts, and
- Seasonal information regarding winter icing and high and low flow events.

3.1.2.1 Industry Dredging Capabilities and Equipment Types

The selection of dredging equipment will depend primarily upon the availability and types of equipment within the dredging industry, both locally and outside the area. A dredge market survey will be necessary to identify:

- Available equipment,
- Types of equipment,
- Contractor experience with specialized equipment,
- Equipment production rate capabilities,
- Equipment removal efficiencies, and
- Equipment contaminant resuspension controls.

3.1.2.2 Commercial and Recreational Vessel Traffic

The Brown County website (http://www.co.brown.wi.us/solid_waste/port/) indicates that approximately 200 commercial ships visit the Port of Green Bay annually. In addition, recreational boaters use the Lower Fox River.

Vessel traffic along the river influences selection of equipment. The impact to dredging equipment selection by navigation will be assessed in terms of the volume and types of vessel traffic. An assessment of vessel traffic will require coordination with entities such as the U.S. Coast Guard (USCG) station in Green Bay, the Port of Green Bay, and the industries along the Lower Fox River. In addition, lock records may be reviewed.

3.1.2.3 Bathymetry

Current bathymetric data is required for selecting appropriate equipment because the water depth can limit using certain types of dredges. As discussed in Section 3.1.1.4, new bathymetric data to be acquired by Retec in summer 2004 should be adequate for use during design activities. Investigation is ongoing as to how the new data will integrate with upland topographic information. If the data are determined insufficient for design activities, then a focused supplemental survey may be necessary to support remedial design.

3.1.2.4 Currents

Anticipated seasonal river current information is important to equipment selection and dredging techniques. Existing data regarding flow velocities, as discussed in Section 2.2.6.2 and displayed in Table 2-8, provide adequate information for this evaluation. No further data collection is expected for design purposes.

3.1.2.5 Presence of Significant Debris and Dredgeability of Dredge Material

Significant quantities of debris can impact the ability of different equipment to effectively and feasibly dredge an area while protecting water quality. The dredgeability of material (Sections 2.6.2.6 and 2.6.4.8) affects the ability to feasibly use certain equipment. The process for verifying existing debris areas and identifying any new areas is discussed in Section 3.1.1.2. Additional sampling required to obtain adequate material dredgeability information is discussed in Section 3.1.1.5.

3.1.2.6 Transport, Dewatering, and Disposal Considerations

The selection of dredge equipment is closely tied to the transport, dewatering, and disposal methods chosen for the remediation. Disposal distances, upland disposal site capacity, and water management of hydraulically dredged sediment all impact the equipment selection process. Currently, these distances, capacities, and dewatering methodologies have not been fully developed. The information required (e.g., elutriate samples, leachate samples, upland borings, inventory of easements and right-of-ways) for further development of transport, dewatering, and disposal options is discussed in Section 3.2.

3.1.2.7 Accessibility of Equipment into Various Cleanup Areas

Access to the remedial areas will be achieved either through direct transit on the river or by launching equipment from shore (Section 2.6.4.12). Transport of dredged sediment to disposal locations may be via pipeline or trucks. An assessment is needed to define access points, easements, right-of-ways, and potential staging areas. These access locations and staging areas may require the establishment of multiple site access agreements. Additional research is necessary to establish potential access and staging areas and associated requirements.

3.1.2.8 Potential Short-Term Water Quality Impacts

Short-term water quality impacts at the point of sediment and/or debris dredging are evaluated through the use of elutriate tests (Section 2.6.5.2). Potential impacts from mechanical and/or hydraulic dredging will be assessed at the point of dredging and the point of disposal using the DRET and/or MET, respectively. The MET and DRET procedures will be modified, as appropriate, for use in assessing short-term water quality impacts at the points of dredging and disposal to be consistent with the proposed dredging methods under consideration. The testing results will provide input data for the DREDGE model (Hayes and Je, 2000) to predict water quality impacts at the point of dredging for contaminant transport. The DREDGE model will also be used to assess the predicted TSS concentrations resulting from dredging operations. If water quality criteria are required to be based on turbidity (Nephelometric Turbidity Units [NTU]) exceedances, it may be necessary to establish a site-specific correlation between TSS and NTU using laboratory measurements from a CST.

Elutriate samples will be collected from three locations in OU 3, four locations in OU 4, and one location, as needed, in OU 5 at the mouth of the river. Up to eight composite samples will be collected from a representative range of PCB concentrations in the OUs, and will include composite samples which contain greater-than-average PCB concentrations representing reasonable worst-case conditions. Based on the results of the elutriate testing and evaluation, the need for and/or scope of water quality BMPs will be identified.

3.1.2.9 Seasonal Restrictions

Information regarding seasonal restrictions due to winter icing, low water levels in the summer, and winter storms resulting in high current velocities are adequate for the design (Section 2.6.5.3). No further information is required for the development of the dredge plan.

3.1.3 Dredge Plan Design Considerations

As previously discussed in Section 2.6.2, the dredge plan design is developed to take into account many factors, with the primary objective to ensure that all required contaminated sediment is removed to the degree that it is feasible.

The required extent of remediation will be defined by using existing data and new data to be collected in summer 2004. The existing and new cores will be the primary source of information to define the extent of contamination. Existing surrogate data will then be used to interpolate between coring data to further define the extent of contamination. Surrogate data will be reviewed against new coring data to develop an appropriate correlation.

Once the extent of contamination has been established and agreed upon, required dredge elevations will be set at or below the bottom of the contaminated sediment layer to ensure that all the required contaminated sediment will be removed. Because of the inherent lack of positioning accuracy of dredging equipment, the required dredge elevations are typically specified as a constant elevation over a specific area, referred to as a DMU. A final dredge plan typically resembles a patchwork of multiple DMUs, each DMU with a different required dredge elevation. The DMUs will be sized appropriately (i.e., dredge cut widths and lengths) to maximize the efficiency for the selected dredging equipment.

Because the required dredge elevations in the dredge plan will always be at or below the bottom extent of contamination, the dredging will result in removal of sediment that falls below the RAL, providing a contingency against leaving contaminated sediment. Also, due to dredge equipment tolerances, an allowable overdepth will be specified. The allowable overdepth represents an additional contingency to ensure that contaminated sediment is removed.

In addition to the extent of contamination, other criteria affect the final layout of the dredge plan. These other criteria are discussed in Section 2.6.2. Some of these factors affect the feasibility of removing all of the contaminated sediment that exceed the RAL; for example, structural stability issues or presence of utilities may require adjusting the dredge plan to avoid impacting these structures, thus requiring other remedial action than dredging.

3.2 Material Handling, Dewatering, and Disposal Site Design Data Gaps

The ROD for OUs 3, 4 and 5 of the Lower Fox River and Green Bay Site specifies that dredged sediment will be disposed of in a Wisconsin Administrative Code NR 500 engineered landfill (WDNR and USEPA, 2003). To address this requirement, early remedial design documents (e.g., the Basis of Design Report) will include the development and implementation of a methodology to evaluate potential disposal options. The objective of this evaluation will be to develop cost-effective option(s) for the sediment segregation, dewatering, and disposal, including options, if necessary for the disposal of material containing PCB concentrations equal to or in excess of 50 ppm.

The initial step of this evaluation will include the preliminary identification of potential disposal options and a list of criteria to evaluate each option. The criteria could include: technical feasibility, existing capacity, compatibility with the remedial action, transport options, applicable siting and permitting feasibility, local approvals, compliance with legal requirements, schedule, cost, social acceptance, political acceptance and any need for development of an Explanation of Significant Differences (ESD) or ROD Amendment. It is possible that criteria may be added or subtracted as the methodology is developed and implemented during conduct of the remedial design.

During the second step of the evaluation, the criteria will be grouped into “Threshold”, “Implementability” and “Modifying” categories. The Threshold category will include criteria designed to aid in eliminating disposal options that are clearly not compliant with legal requirements or are clearly not technically feasible. Potential disposal options will be ranked on a qualitative pass/fail system in relation to each Threshold criterion. If the potential option passes each criterion, it will be evaluated further. If a potential option fails any of the Threshold criteria, it will no longer be considered as a disposal option.

Implementability criteria will then be used to provide a means of ranking potential disposal options against each other. Implementability criteria will include items such as the lead-time needed to prepare the specific option, e.g., construction, permitting, etc., compatibility with contaminated sediment transport options and preliminary estimated cost. The potential disposal options will then be evaluated by a priority ranking system within each criterion. Options with the highest ranking will be retained for further evaluation.

Modifying criteria will then be used to assist in the identification of the most promising disposal options. Often modifying criteria cannot be quantitatively evaluated but are of significant importance in a disposal selection process. These will include criteria such as social and political acceptance.

Finally, the potential disposal options will be assembled and ranked against the selected criteria in the categories described above and a short list (e.g., 2 or 3) of those options ranking the most promising will be identified with supporting rationale and documentation. This short list of disposal options will be presented in the Basis of Design Report along with the full evaluation process. Subsequent evaluation, selection and actual design of these option(s) will then occur in the later design phases of the project.

3.2.1 Data Needs for Remedial Design Evaluation of Sediment Disposal Options

A primary objective of the remedial design activities described in this RD work plan is to collect sufficient data necessary to design the ROD-selected remedy, including upland disposal. As stated above, the initial step of the evaluation process is to identify potential sediment disposal options for prospective sediment to be dredged from OUs 3 and 4 (along with portions of OUs 2 and 5). Data required to perform evaluations of candidate options can be grouped into two general categories: (1) data that are common to all or substantially all prospective disposal options/sites; and (2) data that are specific to an individual disposal option or facility under consideration, including: existing landfills, undeveloped landfill sites, and CDFs (i.e., a facility that provides for dewatering and/or disposal at the same location, such as the facility described in the ROD for OUs 3 through 5, [WDNR and USEPA, 2003]). The following subsections list the identified data gathering needs required for design-level evaluations of each of these prospective disposal options.

Because of the multi-faceted and multi-year remedial design/remedial action activities anticipated in OUs 2 through 5, there is a need to maintain flexibility with respect to potential sediment disposal sites. Accordingly, alternative disposal options such as CAD in Green Bay and vitrification (see Section 3.2.5) may potentially be considered during remedial design if identified as part of an ESD or ROD Amendment process. Evaluation of sediment disposal in a CAD may also be integrated as appropriate with related Water Resources Development Act (WRDA) authorities including maintenance of federally authorized navigation channels and ecosystem restoration. Considerations relative to potential disposal of TSCA-regulated material are discussed in Section 2.7.1.1.

3.2.1.1 Existing Landfills

Existing landfills in the region have been constructed and permitted to receive solid waste materials. Therefore, the design data needs for these facilities assumes that the landfills would only receive sediment that has been dewatered to pass the paint filter test and meet appropriate material strength requirements for that landfill. Existing landfills within approximately 60 miles of Fox RM 3.5 will be evaluated regarding their current design, permit and operating conditions, as well as locational concerns, by considering the following:

- Plan of Operation Approvals
- Local Siting Agreements
- Available remaining capacity vs. capacity requirements
- Phasing flexibility
- Existing infrastructure
- Expansion potential specific to Wisconsin Administrative Code NR 500 Locational Criteria
- Facility operating record and compliance with State codes
- Transportation routes and associated costs
- Potential tipping fees
- Potential timeline for any additional permitting or approval activities
- Required in-field geotechnical evaluations at the landfill site (if any)
- Required pre-design sampling work for a landfill receiving dewatered sediment (Section 3.2.1.4)

3.2.1.2 Undeveloped Landfill Sites

Undeveloped landfill sites could be developed to receive dewatered sediment and/or a sediment slurry. Although these types of sites certainly have potential to serve as a disposal location for the sediments, it needs to be recognized that the state licensing and local approval process typically takes several years to complete. Potential sites within 60 miles of Fox RM 3.5 will be evaluated for design, permit and locational concerns associated with disposal of dewatered sediment. Recognized inefficiencies in piping a sediment slurry over increasing distances (e.g., number of booster pumps required, pumping pressures, etc.) limit the distance between the river and any potential CDF receiving a sediment slurry by pipeline.

Undeveloped sites include those sites with an existing Plan of Operation or Feasibility approval from the WDNR for solid waste disposal. These sites typically have an approval for construction issued by WDNR to the permitee, but have yet to construct the first waste disposal cell. The remedial design evaluation of undeveloped sites would consider the following:

- Identification of suitable but undeveloped sites within an appropriate radius
- Plan of Operation Approvals (if applicable)
- Local Siting Agreements (if applicable)
- Available capacity vs. capacity requirements
- Phasing flexibility
- Expansion potential specific to Wis. Admin. Code NR 500 Locational Criteria
- Transportation routes and associated costs
- Potential tipping fees
- Potential timeline for permitting and approval activities
- Required in-field geotechnical evaluations at landfill site (if any)
- Required pre-design sampling work for a landfill/CDF receiving dewatered and slurried sediment (Section 3.2.1.4)

3.2.1.3 Confined Disposal Facilities

Sediment CDFs are engineered structures typically designed to receive sediment or a slurry and then retain the solids with appropriate transfer of the carriage water or supernatant to a water treatment facility. CDFs could be sited at undeveloped sites. In addition, CDFs could also be sited and designed as either upland or near-shore facilities. It is assumed that the siting of CDFs would be limited by recognized inefficiencies in piping a sediment slurry over increasing distances (e.g., number of booster pumps required, pumping pressures, etc.).

The evaluation criteria for CDFs would be similar to those stated above for undeveloped disposal sites and would consist of:

- Identification of suitable sites
- Plan of operation approvals (if applicable)
- Local siting agreements (if applicable)
- Available capacity vs. capacity requirements
- Expansion potential specific to NR 500 Locational Criteria (if applicable)
- Transportation routes and associated costs
- Potential tipping fees
- Potential timeline for permitting and approval activities
- Required in-field geotechnical evaluations at CDF site (if any)
- Required pre-design sampling work for a landfill receiving a slurried sediment (Section 3.2.1.4)

3.2.1.4 Pre-Design Sampling Data Gaps for Candidate Landfills/CDFs

To prepare a remedial design-level evaluation of candidate segregation, dewatering, and disposal options, data would need to be obtained for OUs 2–5 sediments and also for landfill/CDF operational procedures and estimates. Table 3-1 presents a summary of data needs identified for the design-level evaluation. The data needs presented in Table 3-1 are based upon technical and regulatory requirements that are commonly applied to landfill and CDF disposal evaluations.

3.2.2 Data Needs for Transport (Material Handling)

Dredging operations may require dewatering, material handling and water treatment activities to prepare (or condition) the removed sediment for transport and disposal. Interdependence exists in the selection, evaluation and design of these components, with the selected technologies dependent on the volume of sediment to be removed and the type of dredge conducting the removal. These evaluations will also be performed to assist in equipment sizing and the type of facilities (and practices).

In this section of the work plan the various transport, dewatering, material handling and water treatment data gaps are recognized and assessed. During remedial design, the interdependence of these technologies will be considered.

3.2.2.1 Hydraulic Transport

Hydraulic transfer is the process of pumping dredge slurry from a point of generation to a point of processing or disposal, utilizing a series of pumps and forcemains (pipes) to move the dredged sediment as aqueous slurry. The RODs for OUs 2, 3, 4 and 5 have proposed a baseline process of hydraulic dredging with hydraulic transport of the slurry a maximum distance of 18 miles to a series of passive dewatering basins and ultimately disposed of in an adjacent or nearby monofill.

The process of hydraulic transport is compatible with several remedial options. Two logical combinations include the following:

1. Consistent with the ROD remedy for OUs 3, 4 and 5, hydraulic transport would convey slurry from a hydraulic dredge or hybrid processing unit via a combination of in water and overland routes, to a CDF.
2. An alternative use of hydraulic transport would be to convey slurry directly from a hydraulic dredge or hybrid processing unit via an in-water route to a riverside mechanical dewatering plant.

As indicated in Section 2.6, the design of a slurry forcemain and intermediate booster pumps is closely linked to the output of the dredge, in terms of slurry flow rate and slurry solids concentration. Sizing of the pipe and pumps cannot be completed until the dredge output is known. However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be evaluated during remedial design. These parameters may include:

- Materials separation prior to entering the forcemain;
- Slurry solids concentration, percent by weight;
- Pipe materials of construction;
- Pipe diameter;
- Booster pumps' capabilities and power requirements; and
- Typical system appurtenances (e.g., cleanout points along the pipeline route, air relief at pipe transitions, etc.

In addition, in evaluating the design of a forcemain/booster pump system, effectiveness and reliability of these systems at other locations must be considered. The routing of the forcemain and the siting of intermediate booster pump stations cannot yet be established because of unresolved issues involving the type and locations of slurry processing facilities and the type of dredge employed.

3.2.2.2 Barge Transport

The use of barges as a means of sediment transport in OU 3 and OU 4 is considered a feasible method for transfer of mechanically dredged sediment. During dredging, continuous tugboat and barge movement would be required to complete the implementation of the dredging operations within a reasonable timeframe.

Barge transport, though certainly a viable option, will need to be assessed based on the type of dredging, nature of the dredged sediment, and the efficiency of this method of sediment transport from the remedial site to the transfer facility. However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be further evaluated during remedial design. These parameters include:

- Type of dredging (mechanical or hydraulic);
- Volume of in-place sediment dredged;
- Duration of barging season in Wisconsin;
- Maximum allowable hours per day; and
- Handling of generated effluent.

3.2.2.3 Truck Transport

Trucks could be used to transport sediment to a treatment or disposal facility. This method of transport is compatible with several remedial options. Two logical combinations include the following:

- Dewatered dredge solids, in the form of sand and filter cake, could be transported from the coarse separation/dewatering plant to an off-site treatment or disposal facility (e.g., vitrification plant or landfill/CDF).
- Mechanically dredged sediment, after free water is allowed to drain, could be transported from a barge or riverside processing site to an off-site treatment or disposal facility.

The transport of sediment in either scenario would be performed using standard over-the-road vehicles. The material would be loaded, sufficiently “dewatered”, using conventional earthmoving equipment or conveyors. The loadout facility would be equipped with paved access roads and a weigh scale. Commercial hauling of bulk quantities of material as described is a commodity service, readily accomplished with local resources. However, certain minimum parameters are likely to be relevant for this method of transport, and will need to be further evaluated during remedial design. These parameters include:

- Type of dredging (mechanical or hydraulic);
- Volume of in-place sediment dredged;
- Maximum allowable trucking hours per day;
- Required loadout rates;
- Frequency of truck traffic and impacts to local roads/communities;
- Typical time for a roundtrip; and
- Transporter and manifesting requirements.

In addition, a trucking operation would have implications to the following upstream and downstream elements of this project; dewatering plant capacity, loading equipment, and the unloading station. All of which would be addressed during remedial design.

3.2.2.4 Rail Transport

Wet or dewatered sediment could be transported via rail. However to employ this option, both the riverside processing site (where the sediment is transferred from the river or is dewatered) and the treatment or disposal site must have rail access. The preferred arrangement at the loadout location would be to have two parallel sidings – one for staging of empty cars, and one for staging of loaded cars.

Though a viable transport option, the feasibility of rail transport is contingent on the following factors; is their sufficient property conveniently located to existing rail service for the staging of the requisite number of railcars, does an economical, rail-accessible, disposal option exist, and if so is that option compatible with the removal component.

Based on the interdependence of these factors, certain minimum parameters are likely to be relevant for this transport option, and will need to be further evaluated during remedial design. These parameters include:

- Rail availability in the Fox River Valley;
- Generated quantities of material;

- Required loadout rate;
- Number of rail cars per day;
- Minimum staging area for requisite number of railcars; and
- Available rail-accessible disposal options.

3.2.3 Data Needs for Dewatering

This section of the work plan describes the various dewatering techniques that will be accessed during remedial design, and data gaps that pertain to each. During the remedial design for OUs 3, 4, and 5, the interdependence of these technologies with various sediment removal and disposal options will be considered. Although geotubes are being considered for application in OU 1, the relatively large sediment volumes anticipated in OUs 3 and 4, and the limited availability of land for passive dewatering, largely precludes application of the geotube technology for this project.

3.2.3.1 Coarse Material Separation

The process of coarse material separation will vary according to the type of dredging that is used and the manner in which the dredged material will be dewatered. In all cases, the objective is to remove objectionable material or solids that will interfere with the downstream processing of sediment and if possible, to separate solids which could have beneficial reuse potential.

In a typical separation process bulk debris and very coarse materials are separated first (greater than 5 cm in size), followed by separation of as much of the sand as possible from the soft sediments. Historically, for some remediation projects, the sand fraction that is separated from the dredge slurry has been beneficially reused. The sand fraction of the solids in the soft sediment of OUs 3, 4 and 5 ranges from 20 to 40 percent or greater, representing a significant fraction of the total volume of solids that may need to be dredged. Handling the coarse solids in a separate waste stream would allow for the possible beneficial reuse of the sand/gravel fraction. This would be assessed during the remedial design.

However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be further evaluated during remedial design. These parameters include:

- Type of dredge used for removal (hydraulic or mechanical);
- Volume of dredged material;
- Percent solids on in-place river sediment;
- Percent sand versus silt/clay;
- Specific gravity of the solids;
- Percent sand removed with typical processes; and
- Post-separation materials handling (including assessment of beneficial reuse).

The most significant information need for the final design and the selection of separation equipment is a more definitive characterization of sediment physical properties. This work will be addressed in the pre-design sampling program for the summer of 2004.

Specific data will include grain size analyses and sand fraction specific gravity. In addition, bench scale testing of separation techniques and analysis of residual PCBs remaining in the separated sand will help determine the viability of beneficial reuse of this material.

3.2.3.2 Mechanical Thickening and Dewatering

The processes of thickening and dewatering, using mechanical devices, typically follow coarse separation. The thickening step of the operation is to concentrate the remaining solids in the separated dredge slurry providing a more consistent flow to the downstream dewatering processes. Providing a more consistent flow of higher solids loading to the dewatering equipment greatly improves their efficiency.

The thickening operation may be aided by the addition of polymer. Supernatant (i.e., overflow) from the "thickener" would be a low-solids aqueous stream that could be pumped to the effluent treatment plant. The thickener underflow, or dewatering process feed stock, would then be pumped to the selected dewatering equipment.

The dewatering process will most likely be chosen from the following; plate-and-frame filter presses (standard or diaphragm plates), belt presses, or centrifuges. There is relatively good data from the Fox River Demonstration Projects (Deposit N and SMU 56/57) on filter press efficiency. Unfortunately, there is not a comparable body of experience with belt presses or centrifuges. During remedial design, bench scale testing of dewatering techniques may be performed to determine the viability of belt presses and centrifuges. This would also include polymer testing.

However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be further evaluated during remedial design. These parameters include:

- Volume of dredged material;
- Polymer requirements;
- Unit operations required for thickening, dewatering and supernatant collection and pumping (treatment is discussed in Section 3.2.4);
- Capacity;
- Filter cake solids, percent by weight – disposal requirements; and
- Filter cake unconfined compressive strength (pounds per square inch [psi]) – disposal requirements.

3.2.3.3 Settling Basin

Settling basins are structures used for dewatering solids from the dredged sediments and allow effective handling and disposal of sediments. Settling basins could be used in conjunction with either hydraulic or hybrid dredging. The ROD for OUs 3, 4 and 5 has proposed a baseline process of hydraulic dredging with hydraulic transport of the slurry a maximum distance of 18 miles to a series of passive dewatering basins, or settling basin.

Dredged sediments are pumped to the settling basin and allowed to gravity settle. The supernatant (i.e., overflow) is pumped to the effluent treatment plant, and the resulting wet solids are allowed to “dewater” prior to removal and re-handling for transport to a disposal option. A number of techniques could be employed to aid in the dewatering process (e.g., vacuum enhanced under drain system, perimeter and interior trenching, etc.).

However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be further evaluated during remedial design. These parameters include:

- Average and range of sand content in dredged material;
- Average specific gravity;
- Dredge slurry flow rates;
- Minimum dredge duration;
- Total in-place dredge volume;
- Settling time;
- Consolidation or "dewatering" rate (e.g., 12, 24, 36 months);
- Basin design (liners, slopes, under drain systems, etc);
- Weir design;
- Supernatant collection and pumping system; and
- Availability of sites.

In order to further refine settling basin design calculations, the DRET MET, and CST treatability testing will have to be performed on representative samples.

3.2.4 Data Needs for Effluent Treatment

Carriage water (effluent) from a hydraulic or hybrid dredging operation will require treatment prior to discharge back to the Fox River. The kind of system necessary for this purpose would be comparable to an industrial wastewater treatment plant that is designed for removal of suspended solids and dissolved organics. The concepts and design basis for such a facility are discussed in this section of the work plan.

3.2.4.1 Effluent Treatment

For the purposes of this evaluation, effluent is defined as the water that is released from the dredge slurry as supernatant from the thickening process and/or the settling basin and from mechanical dewatering processes. In addition to the effluent, certain precipitation runoff water, equipment wash water and possibly landfill decant water and leachate will also require treatment. Based on a review of previous water quality evaluations in the Lower Fox River, the principal characteristics expected to dictate the treatment process will be TSS, PCB concentrations, biological oxygen demand (BOD), ammonia, and mercury concentrations in the effluent to be treated.

General water treatment methods include clarification, filtration, and granular activated carbon (GAC).

The sequence, combination of operations and sizing of the equipment will be dependent on certain minimum parameters that need to be further evaluated during remedial design. These parameters include:

- Hydraulic loading;
- Solids content;
- Flow rate (gallons per minute);
- Operations, hours and days;
- Chemical characteristic data;
- Minimum processes required; and
- Effluent limits.

Additional bench scale testing with representative effluent will need to be performed during remedial design.

3.2.4.2 Solids Handling and Plant Infrastructure

The handling of solids residuals from the coarse separation/mechanical dewatering operations will include the facilities and methods for conveying, staging (stockpiling), reclaiming and loading materials. The facility for performing these operations would be integrated with the overall dewatering and effluent treatment plant infrastructure. The design of the solids handling facility and other plant infrastructure will be based on the final process sizing, loadout schedule, and the property constraints.

However, certain minimum parameters are likely to be relevant for any configuration of facilities and will need to be further evaluated during remedial design. These parameters include:

- Total solids volume;
- Solids staging capacity;
- Segregation;

- Loadout access;
- Stormwater control; and
- Available utilities.

3.2.5 Data Needs for Solids Treatment

3.2.5.1 Vitrification

Vitrification is identified in the ROD for OUs 3, 4, and 5 as an alternative remedy. Vitrification is the process of converting solid, semi-solid or liquid material into a glass-like compound. The MINERGY process is one type of vitrification technology.

However, certain minimum parameters are likely to be relevant for consideration of this technology and will need to be further evaluated during remedial design. These parameters include:

- Scaleup considerations;
- Dryer feed requirements;
- Dryer operations;
- Melter feed requirements;
- Melter operations;
- Heat recycle considerations / thermal residuals;
- Preprocessing;
- Glass handling;
- Permitting and siting;
- Waste manifesting;
- Beneficial reuse and current market; and
- Cost calculations.

3.3 Contingent Capping Remedy Data Gaps

3.3.1 Physical Properties

As discussed in Appendix B, in situ capping is a contingent remedy that, if determined to be feasible and approved by the Response Agencies, may be implemented in appropriate areas of OUs 3 and 4. Geotechnical data necessary to adequately design an in situ capping remedy are, for the most part, similar to those described in Section 3.1.1.5 for the dredging remedy design. However, the following additional geotechnical and physical data will be necessary to support in situ cap design:

- In situ vane shear strength;
- Laboratory shear strength (vane shear and/or unconfined compression test, if feasible);
- Consolidation characteristics;
- Observations of potential sand stringers within existing sediments;
- TOC; and
- Permeability.

The strength testing (in situ field vane and laboratory) will provide a measure of the ability of existing sediment to support the weight of an in situ cap, and help determine effective methods for placing a cap without excessive mixing. The compressibility of the existing soft sediments will be evaluated to determine the likelihood of pore water advection into the cap as a result of cap placement-induced consolidation. The results of this evaluation will be used in conjunction with pore water chemistry data, collected as described in the next section, in future contaminant flux modeling for cap design.

As discussed in Appendix B, advective flow of groundwater from deeper deposits through the river bottom is expected to be negligible based on the presence of a relatively impermeable subsurface layer. This assumption will be verified through analyses of cores and borings advanced within potential capping areas for the presence of sand stringers that may allow advective flow. If necessary, CPT may be performed in select locations to provide a more detailed subsurface profile as compared to traditional drilled boreholes. The CPT measures resistance to penetration of a calibrated cone, which can be correlated to grain size and other parameters. One of the advantages to the CPT over a traditional bore hole is that a continuous profile can be obtained with depth, such that thin sand seams, if present, may be more easily identified with the CPT. However, soil samples can not be collected with the CPT.

Sample collection for cap-specific testing will be concentrated in area of potential in situ capping as identified in Appendix B. Furthermore, the results of previous investigations will be used to inform the selection of sample locations within potential capping areas such that the variability of physical properties can be identified.

3.3.2 Chemical Properties

Existing sediment chemical characterization data, supplemented with the more detailed core sampling delineation described above, are anticipated to be sufficient to support remedial design of the contingency in situ capping remedy. Sampling for additional data necessary for design will be concentrated in areas identified in Appendix B for potential in situ capping.

Samples with representative PCB concentrations collected during summer 2004 will be composited for chemical testing. Up to eight composite samples will be collected for leachate testing, including three samples from OU 3, four samples from OU 4, and one sample from OU 5, if needed. Composite samples will be subjected to the pancake column leach test (PCLT) (previously known as the thin-layer column leach test [TCLT]) using water from Lake Winnebago as the leachant. These tests will be used to simulate the quality of pore waters expulsed during the consolidation of existing contaminated sediments resulting from disposal and/or cap placement. Pore water/leachate will be analyzed for low level PCBs (congener determination) and mercury (gold trap determination), and the results used in future contaminant flux modeling to evaluate long-term water quality at the point of disposal (Section 3.2), or for in situ cap design.

3.4 Baseline Monitoring and Natural Recovery Data Gaps

As discussed in Section 2.8, Monitored Natural Recovery (MNR) is the preferred remedial alternative in the following areas:

- OU 2 (Appleton to Little Rapids, excluding Deposit DD)
- OU 5 (Green Bay)

In addition, MNR may potentially be considered to address relatively low-level dredging residuals in remaining areas. Based on the data review summarized in Section 2.8, no further information is needed to support remedial design of MNR elements as may be applied to these areas.

As set forth in the RODs, baseline and post-construction monitoring of the Lower Fox River and Green Bay would include the following components:

- Surface sediment performance monitoring following completion of remedial actions;

- Long-term verification monitoring of surface sediment (in MNR areas), water, and fish tissue to measure progress toward and achievement of RAOs;
- Institutional controls, as needed, to restrict access or use of the Site during the recovery period. Institutional controls would primarily consist of fish consumption advisories and fishing restrictions. In addition, site access restrictions or land and water use restrictions may be considered.
- Additional evaluation, as needed, of contaminant distributions, risks, fate and transport processes, and recovery times.

Long-term monitoring of sediment, water, and fish tissue is specified in the RODs to measure the progress toward achieving the Site's RAOs. Monitoring would continue until acceptable levels of PCBs are reached in these environmental media. As set forth in the AOC, long-term monitoring plans will be developed as part of intermediate remedial design documents, specifically as part of the Operations, Maintenance, and Monitoring Plan (OMMP).

4 REMEDIAL DESIGN PHASES

As set forth in the AOC, the Respondents have agreed to design the selected cleanup remedy for OUs 2, 3, 4, and 5 to meet the ROD requirements (i.e., dredging and transport to an upland disposal facility), and where appropriate to evaluate practicable design alternatives. After initial RD planning (as contained in this RD Work Plan) and summer 2004 data collection tasks (as described in the accompanying SAP; Shaw and Anchor, 2004a), subsequent RD tasks will evaluate baseline and alternative scenarios for the various components of the remedy, culminating in detailed engineering design documents. Consistent with AOC/SOW requirements, subsequent RD activities are described in the sections below.

4.1 Initial Remedial Design Activities

As discussed previously, a primary objective of remedial design activities described in this RD work plan is to design the ROD-selected remedy, including dredging and upland disposal. Concurrent with these activities, alternative disposal/treatment options and contingent capping remedies will also be evaluated.

Following receipt of validated sampling and analysis data collected in summer 2004, Respondents will evaluate existing data along with the data collected in the pre-design sampling in order to meet the following data evaluation objectives:

- To define the area and volume of sediment requiring remediation through spatial resolution of surface and subsurface PCB chemical concentration distributions;
- To define the physical and chemical nature and features of the sediment (e.g., grain size, TOC, sediment stability, and load-bearing properties) and the river channel (e.g., currents, slope and engineered structures) necessary for implementation of the remedy described in the ROD and, if appropriate, the contingent remedy (capping);
- To assess on a preliminary basis the sediment contaminant mobility in connection with dredging and capping, including: column leach tests, pore water test, standard elutriate test, MET, and CSTs;
- To establish baseline conditions of those features that may be altered during the remedial action, such as bathymetry and sediment quality;
- To evaluate potential integration of current and planned property uses (e.g., WRDA authorities, maintenance dredging, and piers/berthing areas) with prospective remedial actions; and
- To determine additional data needed for remedial design.

Concurrent with the pre-design data evaluation task outlined above, the Respondents and Response Agencies will also jointly perform a focused evaluation of potentially practicable disposal options and technologies. This work will involve a number of tasks designed to further refine the options and technologies for sediment dredging and the dewatering, transportation, treatment and disposal of dredged sediments and associated wastewaters. These tasks will build upon previous engineering analyses. A variety of tasks will be undertaken in this phase of the RD, including the following:

- **Identification and Screening of Dewatering, Transport, Treatment and Disposal Options**: Respondents will develop an inventory of potentially available disposal sites in the Fox River/Green Bay area, as well as potential dewatering, transport, and treatment technologies and locations, that are individually capable of handling at least 500,000 cy of sediment. Only those with a reasonable probability of success in meeting the needs of this project will be considered. The disposal site inventory will then be subject to screening based on effectiveness, implementability, and cost, in order to develop a list of the most promising disposal sites that would be subjected to further evaluation and stakeholder outreach (Section 2.7.1).
- **Stakeholder Outreach for Preliminary Disposal Locations.** After the initial screening performed as outlined above, the Response Agencies and Respondents will together begin planning an outreach effort with respect to those parties with an interest in the dewatering, transportation, treatment, and disposal options identified. As described in the SOW, stakeholder outreach will be initiated following approval of the Basis of Design.

In addition, it is expected that the remedial design and much of the remedial action for OU 1 will be occurring during the RD for OUs 2–5. As data, information, and analysis become available from the OU 1 work (OU 1 Work Information), it will be incorporated as appropriate into the RD. While the OU 1 Work Information will be important for all phases of the RD, and will be regularly taken into account, such information will be especially important for the initial remedial design activities and the Basis of Design Report. The Respondents will endeavor to work with the parties conducting the OU 1 work to ensure that significant data and information from the OU 1 work and any associated pilot projects and supplemental investigations are incorporated into the RD as such information becomes available.

4.2 Preparation of Basis of Design Report

Following completion of pre-design sampling and validation of data, and as described in the AOC/SOW and RD Schedule presented in Section 5, Respondents will submit a Basis of Design Report for review and approval by the Response Agencies. Prior to or in conjunction with the

Basis of Design Report, Respondents expect to submit a detailed technical memorandum supporting proposed contingent capping and/or alternative remedial measures, as discussed in Section 4.3 below. To the extent that an ESD approving capping and/or alternative remedial measures in certain applications is approved sufficiently in advance of submission of the Basis of Design Report, such remedies will be integrated into the Basis of Design Report, as appropriate (see also Section 5). If an ESD is adopted after the Basis of Design Report, the Basis of Design Report will be modified, as appropriate.

The Basis of Design Report shall include preliminary delineations of remediation areas and technologies, and preliminary identifications of dewatering, transportation, treatment and disposal technologies and locations. The Basis of Design Report will also define volumes and areas to be dredged, and will contain analyses of information and data supporting such designation and volumes. The designation of sediment deposits for removal will be subject to approval by the Response Agencies and be consistent with the RODs for OUs 2 – 5, as well as any ESDs or ROD Amendments. The Basis of Design Report will also identify recommended dewatering, transportation, treatment and disposal options. The Response Agencies shall select the appropriate remedy options based on the approved Basis of Design Report.

The Basis of Design Report will include a summary of information collected and analyses conducted during the prior phases of the RD, other data available for the Lower Fox River Site (e.g., OU 1 work information), and appropriate literature and design references. The Report will also include updated identifications of remedial, dewatering, transportation, treatment, and disposal options. For each of the options, the disposal site identification process will include summaries, updates of implementability evaluations and cost estimates. The Basis of Design Report will provide a delineation of the volume and area of sediments covered by the various dredging and capping recommendations, along with associated technical justifications.

Based on this evaluation, the Basis of Design Report will define volumes and areas to be dredged and identify recommended dewatering, transportation, treatment, and disposal options. These recommended remedial design elements will include means and methods for dredging and capping (as appropriate); the locations and technologies for dewatering, transportation, treatment and disposal of dredged sediments and associated wastewaters; plans for monitoring during and after remedial construction; and an estimated schedule. The Basis of Design Report will also provide:

- A demonstration that the design elements meet the nine Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) evaluation criteria (National Contingency Plan (NCP) §300.430 (e)(9)(iii));
- An evaluation of the ability of the recommended design elements to satisfy water quality standards both in the vicinity of any dredging operations and in the vicinity of the treatment and disposal sites, as required under Clean Water Act §401; and
- Information necessary for the Response Agencies to prepare a Clean Water Act §404(b)(1) analysis for the recommended design elements, as necessary.

The recommendations in the Basis of Design Report will be subject to approval by the Response Agencies and will be consistent with the RODs for OUs 2 – 5, as well as any ESDs or ROD Amendments. The Response Agencies will select the appropriate remedy options based on the approved Basis of Design Report.

As described in Section 4.1, the Response Agencies and Respondents will together conduct, as part of the Initial Remedial Design Activities, an outreach effort with respect to those parties with an interest in dewatering, transportation, treatment and disposal options identified in the report (stakeholder outreach). The Basis of Design Report may identify additional stakeholder outreach that must take place before proceeding with the Preliminary Design and that has not already occurred at the time the Basis of Design Report is submitted. The Response Agencies and Respondents will undertake any such additional outreach after approval of the Basis of Design Report.

4.3 Contingent Remedy Evaluations, Pilot Projects, and Supplemental Investigations

If Respondents, consistent with the ROD capping contingency, propose capping in any area as part of the final remedy, Respondents shall provide a detailed submittal with technical justification supporting such a proposal to the Response Agencies for review and approval. This submittal shall be consistent with ROD Sections 13.4 and 13.5 and all appropriate USEPA Guidance. If capping of certain areas were to be approved, an ESD would be required.

Likewise, if Respondents, based on investigation activities and assessments conducted during the design phase, propose that alternative remedial measures be designated by the Response Agencies for any portion of OUs 2–5, Respondents will provide a detailed submittal with technical justification supporting such a proposal to the Response Agencies for review and approval.

Respondents expect to conduct a technical evaluation of the contingent capping remedy, alternative disposal options, and any other alternative remedial measures during the Initial Remedial Design Activities. However, it is possible that, given the progress of initial design activities, the status of the OU 1 work, and the scheduling of supplemental investigations and pilot projects, this evaluation will be completed later than planned, or will be supplemented with additional information and analysis after it is initially completed. In addition, as described below, Respondents may conduct one or more pilot projects after the Initial Remedial Design Activities. As the schedule in Section 5 indicates, Respondents expect to submit any request for the use of contingent remedies or alternative remedial measures in sufficient time to allow the Response Agencies to consider the request and, if necessary, issue an ESD or ROD Amendment before the Basis of Design Report is submitted. Alternatively, the SOW provides that Respondents may make a request for use of contingent remedies or alternative remedial measures in conjunction with the Basis of Design Report, during design, or even after the Final Design is complete, but before remedial action begins in the portion of the river addressed by the request. If a contingent remedy or alternative remedial measure is adopted after the Basis of Design Report is approved, Respondents may have to modify the Basis of Design Report (and potentially the Preliminary, Intermediate, and/or Final Designs) to reflect that decision.

As described in more detail in the RODs, a contingent capping remedy could potentially be implemented in certain areas of the site, subject to specific location and engineering requirements, including site areas where dredging may be infeasible, such as shoreline areas encountered during the SMU 56/57 dredging pilot project. Data compilation and evaluation included in the detailed technical submittal outlined above will assess geotechnical properties of site sediments (e.g., load bearing capacity and slope stability), stability of bottom sediments in response to potential scour forces (e.g., hydrologic flows, ice scour, wind-induced currents, and propeller wash), and chemical transport processes. These data will be used to assess the efficacy of capping at the site, consistent with the RODs and with "*Guidance for In situ Subaqueous Capping of Contaminated Sediments*" (Palermo et al., 1998b).

As provided in Paragraph 28 of the AOC, Respondents may undertake voluntary, supplemental, work relating to OUs 2, 3, 4, or 5, or to remedial design issues not specifically covered in the AOC/SOW. The Response Agencies will review and comment promptly on such work and consider any recommendations made by Respondents based on such work. In developing this RD Work Plan, consideration has been given to conducting pilot projects that would generate useful and significant information for the RD. Potential pilot projects proposed by the Respondents may include:

- A pilot project(s) to assess cap constructability on relatively steep side slope areas (subject to a prior ESD determination); and
- Other pilot projects to assess technologies for dewatering, transportation, treatment and disposal of dredged sediments and associated wastewaters, as appropriate.

4.4 Preparation of Remedial Design Documents

Following completion and approval of the Basis of Design Report, Respondents shall prepare construction plans and specifications to implement the Remedial Action at OUs 2, 3, 4 and 5, as described in the ROD, AOC/SOW, and this RD Work Plan, and consistent with the approved Basis of Design Report. Subject to approval by the Response Agencies, Respondents may submit more than one set of design submittals reflecting different components of the Remedial Action. All design plans and specifications shall be developed consistent with USEPA's Superfund Remedial Design and Remedial Action Guidance (OSWER Directive No. 9355.0-4A), except as otherwise specified in the AOC/SOW or this RD Work Plan, and shall demonstrate that the Remedial Action based on the final RD will meet the objectives of the Consent Order and the ROD, including all Performance Standards. Respondents shall meet regularly with the Response Agencies to discuss and work collaboratively on design issues.

It is possible that additional information from supplemental sampling work, pilot projects, subsequent analysis, or supplemental investigations will become available after approval of the Basis of Design Report and while Respondents are working on remedial design documents. If that is the case, such information will be incorporated into the design documents then under preparation. If necessary, a revised Basis of Design Report will be submitted to reflect the additional information.

4.4.1 Preliminary Design (30%)

Respondents shall submit the Preliminary Design for OUs 2, 3, 4 and 5 within 120 after approval of the Basis of Design Report. Portions of the Preliminary Design that may be completed prior to the entire Preliminary Design should be submitted as they completed. The Preliminary Design submittal shall include or discuss, at a minimum, the following:

- Preliminary plans, drawings, and sketches, including design calculations;

- Determination of specific technologies for sediment dredging, dewatering, transportation and disposal of dredged sediments and associated wastewaters. These determinations will build upon previous engineering analyses;
- Results of studies and additional field sampling and analysis, if any, conducted after the pre-design sampling;
- Design assumptions and parameters, including design restrictions, process performance criteria, appropriate unit processes for the treatment train, and expected removal or treatment efficiencies for both the process and waste (concentration and volume), as applicable;
- Draft Sediment Removal Verification/Capping Plan including the proposed cleanup verification methods (i.e., probing methods) and compliance with ARARs;
- Outline of required specifications;
- Proposed siting/locations of processes/construction activity;
- Proposed disposal locations based upon effectiveness, implementability and cost;
- Draft Mitigation Plan to restore habitats that have been physically impacted by sediment removal equipment or soil excavation equipment (not including the soft sediment deposits themselves);
- Expected long-term monitoring and operation requirements;
- Real estate, easement, and permit requirements;
- Preliminary construction schedule, including contracting strategy;
- Significant new information from other projects and activities on the River (e.g., OU 1 activities) and elsewhere; and
- Draft Adaptive Management Plan for the remedial action.

4.4.2 Intermediate Design (60%)

Respondents shall submit an Intermediate Design within 90 days after approval of the Preliminary Design. The Intermediate Design shall be consistent with Response Agency approval of the Preliminary Design. The Intermediate Design documents will build on those elements listed for the Preliminary Design (30%) documents, and will also include the following:

- Modifications to Plans and specifications in the Preliminary Design (30%) in response to the Response Agencies' comments;
- Draft Construction Quality Assurance Project Plan (CQAPP);
- Draft Operation, Maintenance, and Monitoring Plan (OMMP) for OUs 3 and 4;
- Draft Monitoring Plan for OUs 2 and 5;

- Draft Capital and Operation and Maintenance Cost Estimate;
- Draft Project Schedule for the construction and implementation of the remedial action; and
- The following draft supporting plans:
  - Health and Safety Plan (HASP)
  - Contingency Plan

4.4.3 Pre-Final Design (90%)

The Respondents shall submit the Pre-Final Design within 90 after approval of the Intermediate Design. The Pre-Final Design shall be consistent with Response Agency approval of the Intermediate Design (60%). The Pre-Final Design submittals shall include those elements listed for the Preliminary Design and Intermediate Design, as well as the following:

- Construction Quality Assurance Project Plan;
- Final Health and Safety Plan;
- Final Contingency Plan;
- Final Sediment Removal Verification / Capping Plan;
- Operation, Maintenance, and Monitoring Plan;
- Capital and Operation and Maintenance Cost Estimate. This cost estimate shall refine the FS cost estimate to reflect the detail presented in the Pre-Final Design;
- Final Project Schedule for the construction and implementation of the Remedial Action addressed in the AOC/SOW which identifies timing for initiation and completion of all critical path tasks. The final project schedule submitted as part of the Final Design shall include specific dates for completion of the project and major milestones. Specific dates will assume and be dependant upon, a defined start date.

4.4.4 Final Design (100%)

The Respondents shall submit the Final Design within 60 days after approval of the Pre-Final Design. The Final Design shall be consistent with Response Agency approval of the Pre-Final Design (90%) and shall include reproducible drawings and specifications suitable for bid advertisement. The Final Design submittals shall include those elements listed for the Pre-Final Design.

4.4.5 Content of Supporting Plans

4.4.5.1 Health and Safety Plan

Respondents shall develop and submit to the Response Agencies for review and approval a site specific HASP which is designed to protect construction personnel and area residents from physical, chemical, and other hazards posed by any work at the Site during the RA. The Health and Safety Plan shall follow OSHA requirements as outlined in 29 CFR §§ 1910 and 1926.

4.4.5.2 Contingency Plan

Respondents shall develop and submit to the Response Agencies for review and approval a Contingency Plan that describes the mitigation procedures they will use in the event of an accident or emergency at the Site. The Contingency Plan may be incorporated into the HASP. The final Contingency Plan shall be submitted prior to the start of construction, in accordance with the approved construction schedule. The Contingency Plan shall include, at a minimum, the following:

- Name of the person or entity responsible for responding in the event of an emergency incident;
- Plan and date to meet with the local community, including local, State and Federal agencies involved in the Remedial Action, as well as local emergency squads and hospitals; and
- First aid medical information.

4.4.5.3 Construction Quality Assurance Project Plan

Respondents shall develop and submit to the Response Agencies for review and approval a CQAPP that describes the site-specific components of the quality assurance program that the Respondents shall use to ensure that the completed project meets all design criteria, plans, and specifications. The final CQAPP shall be submitted in accordance with the approved RA Work Plan schedule. The CQAPP shall contain, at a minimum, the following elements:

- Responsibilities and authorities of all organizations and key personnel involved in the construction of the Remedial Action.
- Qualifications of the Quality Assurance Official to demonstrate that he/she possesses the training and experience necessary to fulfill his/her identified responsibilities.

- Protocols for sampling and testing used to monitor the remedial action.
- Identification of proposed quality assurance sampling activities including the sample size, locations, frequency of testing, acceptance and rejection data sheets, problem identification and corrective measures reports, evaluation reports, acceptance reports, and final documentation.
- Reporting requirements for CQAPP activities shall be described in detail in the CQAPP. This shall include such items as daily summary reports, inspection data sheets, problem identification and corrective measures reports, and design acceptance reports, and final documentation. Provisions for the final storage of all OUs 2–5 cleanup records shall be presented in the CQAPP.

4.4.5.4 Sediment Removal Verification/Capping Plan

As a component of the CQAPP, Respondents shall develop and submit a Sediment Removal Verification/Capping Plan to the Response Agencies for review and approval. The purpose of the Sediment Removal Verification/Capping Plan is to provide a mechanism to ensure that Performance Standards for the Remedial Action are met. Once approved, the Sediment Removal Verification/Capping Plan shall be implemented on the approved schedule. The Sediment Removal Verification/Capping Plan shall include, at a minimum:

- Quality Assurance Project Plan (may be part of remedial action QAPP);
- Health and Safety Plan (may be part of remedial action HASP); and
- Field Sampling Plan.

5 REMEDIAL DESIGN PROJECT SCHEDULE

The remedial design schedule for OUs 2–5 is set forth in the AOC and the SOW. This section presents a Gantt chart (Figure 5-1) that depicts a likely scenario in which the AOC/SOW schedule may play out. The schedule also depicts coordination opportunities with separate RD activities occurring in OU 1, and with a related WRDA Feasibility Study. Figure 5-1 is consistent with the SOW and represents the Respondents' best estimate of time frames, sequences and submission dates based on the provisions of the SOW. Since many of the key dates are dependent upon review and approval by the Response Agencies or other activities (e.g., receipt of validated data), the dates in Figure 5-1, except for the initial dates (e.g., submission of Work Plan by March 31, 2004), should not necessarily be considered firm dates.

The AOC and SOW outline due dates for the major remedial design deliverables. Those due dates are as follows:

Deliverable/Milestone	Due Date
Pre-design Sampling Plan	March 31, 2004. This requirement is met by submission of the Sampling and Analysis Plan accompanying this work plan.
RD Work Plan	March 31, 2004. This requirement is met by the submission of this document.
Final RD Work Plan	As provided in the AOC. The AOC provides that Respondents will resubmit any document within 45 days of receiving disapproval from the Response Agencies.
Monthly Progress Reports	As provided in the AOC. The AOC provides that monthly progress reports are due on the 10th day of each month.
Pre-design Sampling	Weather permitting, pre-design sampling will begin within 60 days of approval of the Pre-design Sampling Plan.
Basis of Design Report	180 days after receipt of all validated data form the pre-design sampling investigation. When Respondents have obtained all validated data from the pre-design sampling investigation, Respondents will so inform the Response Agencies in the next monthly progress report. Unless the Response Agencies notify Respondents that they disagree that all validated data have been received, the notification in the monthly progress report will start the 180-day time period for submission of the Basis of Design Report.

5.1 Rationale and Assumptions

The rationale and assumptions used in developing the OUs 2–5 RD schedule are summarized below:

- Pre-design fieldwork and analyses will be completed in summer/fall 2004;
- Evaluation of the 2004 sediment characterization data may determine the need for a second phase of sediment sampling. If a Phase 2 sediment sampling effort is needed, it would be performed in summer 2005. The RD schedule anticipates proceeding with the RD tasks utilizing the data obtained in 2004.
- A separate Contingent Remedy technical evaluation, including the detailed justification for implementing capping and/or alternative disposal/treatment contingencies, will be submitted to the Response Agencies in early 2005. The Contingent Remedy technical evaluation will present conceptual cap design criteria, cross-sections, materials, horizontal extent, minimum water depth requirements, materials supply and staging, and an updated project cost estimate.

If events that form part of these assumptions do not occur as scheduled, the overall schedule would be affected.

6 REMEDIAL DESIGN PROJECT MANAGEMENT

This section describes the OUs 2–5 project management approach, including the following:

- Project organization, responsibilities, and authorities
- Communications

6.1 Respondent Team Organization, Responsibilities, and Authorities

The RD for OUs 2–5 is being managed by Shaw Environmental and Infrastructure, Inc. (Shaw), assisted by Anchor Environmental, LLC (Anchor), on behalf of Fort James and NCR. The collaboration of Shaw and Anchor is referred to as the Shaw/Anchor Team. The project team structure is presented in the organization chart (Figure 6-1). The RD project responsibilities and authorities for various organizations and project team members are outlined below:

6.1.1 Fort James Operating Company, Inc. and NCR Corporation

Fort James and NCR having jointly entered into the Lower Fox River OUs 2–5 RD AOC are responsible for the preparation of the Lower Fox River OUs 2–5 Remedial Design. Fort James is a wholly owned subsidiary of Georgia-Pacific Corporation.

6.1.2 Shaw/Anchor Team

The Lower Fox River OUs 2–5 RD is being managed by Shaw, assisted by Anchor, on behalf of Fort James and NCR. The responsibilities of key Shaw/Anchor personnel directing the RD and key subcontractors are summarized in the following sections.

6.1.2.1 Shaw Project Coordinator, George L. Hicks

As Shaw's project coordinator, Mr. Hicks will perform the following functions:

- Manage Remedial Design;
- Provide overall direction and management of RD project activities;
- Perform administrative and decision-making activities, as well as provide necessary authorizations related to the project;
- Facilitate RD coordination between Shaw and external organizations such as Shaw's subcontractors and the regulatory agencies; and
- Communicate with USEPA and WDNR on an ongoing basis regarding project status and technical issues.

6.1.2.2 Anchor Technical Director, Clay Patmont

The technical director will perform the following functions:

- Provide overall direction and management of the technical scope and approach in support of remedial design.
- Communicate with USEPA and WDNR on an ongoing basis regarding technical issues.

6.1.2.3 Shaw/Anchor Team Senior Consultants

The senior technical consultants on the Shaw/Anchor Team include:

- Todd Thornburg, Ph.D. (Sampling Design);
- Nancy Case-O'Bourke, P.E. (Dredge Design);
- Tom Wang, P.E. (Dredge and Disposal Design;
- John Verduin, P.E. (Capping and CDF Design);
- Tom Schadt (Habitat Integration); and
- Judy Reagan (Data Management).

6.1.2.4 Quality Assurance Manager, Vicki Graves

The quality assurance manager will perform the following functions:

- Direct the quality assurance review of the various phases of the project, as necessary;
- Direct the review of quality assurance plans and procedures;
- Provide quality assurance technical assistance to project staff, as necessary;
- Schedule the analytical laboratories;
- Oversee the tracking of samples and data from the time of field collection until results are entered into a database;
- Coordinate activities with laboratories and data validators; and
- Review laboratory data for compliance with SAP/QAPP.

6.1.2.5 Shaw/Anchor Field Team Leaders, Paul LaRosa/Bernadette Johnston

The field team leaders will be on site during the summer 2004 pre-design sampling effort. They will perform the following functions :

- Instruct and coordinate activities with field staff;
- Direct and participate in field work activities;

- Coordinate field and laboratory schedules;
- Ensure that field activities are conducted according to the SAP and HASP (Shaw and Anchor, 2004a).;
- Ensure that field staff are trained properly to perform field activities according to this SAP (Shaw and Anchor, 2004a), have proper certification (e.g., current Hazardous Waste Operations and Emergency Response training), and are compliant with medical monitoring requirements;
- Inspect and accept supplies and consumables;
- Communicate issues to the project team; and
- Perform oversight of subcontractors.

6.1.2.6 Shaw/Anchor Support Staff

The following individuals will provide project support on an as needed basis during pre-design activities:

- **Shaw Project Chemist, Cheryl Schulz**. Responsible for laboratory contact, sampling data acquisition, and processing site quality assurance/quality control audits.
- **Shaw/Anchor Health & Safety Program Manager, Clifford Florczak**. Responsible for performing oversight to ensure overall project adherence to the HASP from a corporate level.
- **Shaw/Anchor Health & Safety Manager, Erika Lammertin**. Responsible for performing oversight to ensure adherence to the HASP.
- **Shaw/Anchor Project Delivery Manager, Ryan Curry**. Responsible for managing the preparation of reports and submittals and tracking schedule changes and updates.

6.1.2.7 Shaw Subcontractors

The following are subcontractors who will provide technical assistance during this project:

- **Anchor Environmental, LLC**. Principle subcontractor, and as previously described, the other half of the Shaw/Anchor Team
- **Foth & Van Dyke**, Disposal Design Assistance
- **Severn Trent Laboratories (STL)**, Analytical Laboratory Services
- **BB&L Environmental Services (BBLES)**, Summer 2004 Field Sampling Contractor

- **Limno-Tech, Inc**., Statistical Modeling
- **MAKuehl, Inc.**, Data Validation

6.2 Agency Organization, Responsibilities, and Authorities

6.2.1 WDNR Project Coordinator, Greg Hill

- Review all project deliverables, plans and/or approve project strategies;
- Direct review and approval of Work Plans, SAPs, and QAPPs;
- Provide technical assistance to the Respondent Team;
- Review progress reports detailing work accomplished;
- Review all reports in draft version prior to their final edition; and
- Approve final reports.

6.2.2 WDNR Project Manager, Ben Hung

- Review all project deliverables and project strategies;
- Direct review of Work Plans, SAPs, and QAPPs;
- Provide technical assistance to the Respondent Team;
- Review progress reports detailing work accomplished;
- Review all reports in draft version prior to their final edition; and
- Report to and coordinate all activities with the WDNR Project Coordinator (Greg Hill).

6.2.3 USEPA Project Coordinator, Jim Hahnenberg

- Review all project deliverables, plans and/or approve project strategies;
- Direct review and approval of QAPP/SAP;
- Provide technical assistance to the WDNR and the Respondent Team;
- Review progress reports detailing work accomplished;
- Review all reports in draft version prior to their final edition; and
- Approve final reports.

6.2.4 USEPA Quality Assurance Reviewer, Richard Byvik

- Review and approve the SAP/QAPP and provide technical assistance to the USEPA Project Coordinator

6.2.5 WDNR Quality Assurance Manager, Donalea Dinsmore

- Review SAP/QAPP and provide technical assistance to the WDNR Project Manager

6.3 Communications

6.3.1 Monthly Progress Reports

As required by the AOC, the Respondent Team will provide written monthly progress reports to the Response Agencies by the tenth (10th) day of every month.

6.3.2 Meetings

As required by the AOC, the Project Coordinators will hold progress report meetings or telephone conferences twice a month unless such a meeting is deemed unnecessary by the Response Agencies. By mutual agreement the Project Coordinators may hold meetings or telephone conferences at more frequent intervals.

6.3.3 Work Groups

In an effort to achieve a mutually acceptable (and implementable) remedial design, the Respondents and representatives from the Response Agencies will form various Work Groups, as needed (e.g., Work Plan Work Group, SAP/QAPP Work Group, etc.), to make sure that the Response Agencies are involved throughout the design process. Work Groups will meet on a schedule mutually acceptable to both the Respondents and the Response Agencies.

6.3.4 Response Agency Communication Plan

Technical documents, reports, data, comments, schedules, meeting notices and general project communications related to pre-design activities will be distributed electronically to the following Response Agency representatives:

- James Hahnenberg, USEPA – hahnenberg.james@epamail.epa.gov
- Gregory Hill, WDNR – hillg@dnr.state.wi.us
- Ben Hung, WDNR – ben.hung@dnr.state.wi.us
- Gary Kincaid, WDNR – gary.kincaid@dnr.state.wa.us
- Boldt Technical Services, Oversight Contractor –lfr.oversightteam.boldt.com

For documents that are too large to send via email and/or are posted on websites etc., a notice will be sent to the same addresses with information on how to access those documents. One copy of documents requiring hard copy distribution will be sent to the following:

- James Hahnenberg
  USEPA Project Coordinator
  United States Environmental Protection Agency
  77 West Jackson Blvd. (SR-6J)
  Chicago, Illinois 60604-3590
- Gregory Hill
  WDNR Project Coordinator
  Wisconsin Department of Natural Resources
  101 S. Webster St.
  Madison, WI 53703
- Ben Hung
  WDNR Project Manager
  Wisconsin Department of Natural Resources
  101 S. Webster St.
  Madison, WI 53703
- Gary Kincaid
  Wisconsin Department of Natural Resources
  801 E. Walnut St.
  Green Bay, WI 54301
- Richard Johnson
  Oversight Team Manager
  Boldt Technical Services
  2525 N Roemer Rd
  Appleton, WI 54912
- Richard G Fox
  Oversight Team Remedial Design Lead
  Natural Resource Technology
  23713 W Paul Road
  Suite D
  Pewaukee, WI 53072

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TABLES

FIGURES

APPENDIX A – GEOSTATISTICAL METHODS AND RESULTS

This appendix of the RD Work Plan describes the geostatistical method that was used to determine spatial correlation distances for sampling grid design in OUs 2 through 5. The objective of the geostatistical analyses was to calculate semivariograms using surficial and subsurface total PCB concentrations. The structure of the semivariograms reveals the underlying spatial structure of the data. This structure can be interpreted to provide optimal sampling grid spacing. These semivariograms were also used as the basic mathematical relationship for geostatistical interpolation (kriging). The following sections describe the relevant geostatistical background, methods (data preparation, semivariogram calculation and kriging) and results.

BACKGROUND ON KRIGING AND SEMIVARIOGRAM ANALYSIS

Kriging is a form of statistical modeling that interpolates data from a known set of sample points to a continuous surface. Similar to other spatial interpolation algorithms, in kriging estimation is based on a weighted, linear combination of data values within a certain radius from the point being estimated (the neighborhood). Both the weights and the neighborhood are functions of the semivariogram. Two semivariograms can be distinguished (refer to Figure A-3 for a visual representation of the semivariogram features discussed in this section). The experimental semivariogram is calculated from data points and describes the average degree of dissimilarity (semivariance) between them as a function of separation distance (between sampling locations) in space. The model semivariogram is a fitted curve through the points on the experimental semivariogram. The semivariogram is interpreted based on the model.

Three parameters are used to describe semivariograms and to interpret spatial patterns: the *sill*, the *nugget effect* and the *range*. In general, semivariograms are curves with an initial rise and a gradual leveling at a constant value. This constant is known as the *sill*, and it approaches, in theory, the variance in the data. The magnitude of the sill is a measure of overall variability in the data. The top semivariogram in Figure A-3 is typical from the point of view of scatter, the bottom semivariogram displays less scatter than many environmental data sets provide. The critical element however is whether a rising trend can be detected within the scatter of points.

The *nugget effect* is a measure of the variability in the data that is not accounted for by the sampling density. It incorporates measurement, instrumental and sampling uncertainty. In theory, semivariograms should have a value of zero for a separation distance of zero. A separation distance of zero implies that a given point is compared to itself, and as such the difference should be zero as well. A non-zero semivariance at distances approaching zero is what is called the nugget effect. The nugget effect is usually compared to the sill. A nugget effect of 20% of the sill's magnitude means that 20% of the variability is due to the sum of all errors as well as spatial variability at scales smaller than the minimum distance between samples. Conversely, 80% of the total variability has been captured by the sampling scheme. In kriging, both an estimate of local concentration and a kriging variance (uncertainty) are calculated using the semivariogram. The sill determines the magnitude of the uncertainty and the extent to which the data average influences an estimate. In sparsely sampled areas estimates will be more strongly biased towards the mean and will have higher kriging variances.

The *range* is that separation distance at which the sill is reached. It is the distance within which points are correlated and can be used to inform interpolated estimates. In kriging, the range defines the radius of the neighborhood from which data values are taken for interpolated estimates. An important distinction of kriging from other methods is its ability to use data-specific information to determine which points should influence an estimate. As a measure of correlation distance, the range is also interpreted to determine the size of optimal sampling grids. A general rule in the scientific literature is to make the sampling interval one half of the range of the semivariogram (Caeiro et al., 2003). Increasing this density (e.g., one quarter of the range) will make more points available for kriging, which will decrease the uncertainty in locations with critical concentrations, where uncertainty should be minimized. Within the range, the weight of any data point on an estimate is determined as a function of the semivariance.

Anisotropy is the change in spatial relationships with direction. A concentration gradient that is more gradual along the flow direction than in directions transverse to a river's flow is an expression of anisotropy. The phenomenon is often caused by transport or depositional processes acting differently in various directions. As such, anisotropy also often implies that there is more variability within a shorter distance in one direction than in another direction. Anisotropy is modeled explicitly in geostatistics by calculating separate semivariograms (experimental and model) for the two directions that define the axes of anisotropy at a site. In a river, these axes are along the flow direction and perpendicular to the flow direction. While the sill can be different for these two directions, the ranges always are different. In the flow direction, the range will be greater because transport processes influence concentrations over longer distances. Lateral transport is bounded by the river's banks. Thus, the lateral range is usually smaller than the width of the river.

METHODS

Data Preparation Methods. Data from cores and surface samples were available for several years between 1989 and 2000. Surficial total PCB concentrations and core maxima for total PCBs were used for two separate spatial analyses.

Several different river reaches were analyzed separately to evaluate the potential for different sedimentary regimes, data density, and in general, statistically different populations in different parts of the Lower Fox River. OU 3 was analyzed without further sub-sectioning. OU 4 was divided into the southern and northern reaches, OU 4a and OU 4b, respectively. OU 4a has a high density of samples in sediments which have been relatively undisturbed by dredging. In OU 4 b where active maintenance dredging is conducted, the dredged channel (OU 4b-ch) was analyzed separately from the undredged near-bank regions on either side (OU 4b-sd).

Coordinate Transformation Methods. Semivariograms are based on distances between points, and in rivers care must be taken to measure these distances in the direction of mass transport rather than over intervening land, as it would happen around bends and over sections of unequal river width. For this reason, it is appropriate to transform the coordinates of the data such that the river is straightened and its width is normalized. This transformation was accomplished using a Matlab code to create a curvilinear grid within the river and to assign "straightened" coordinates to the grid-nodes and to the data points within the grid. Figures A-1 and A-2 show the location of sampling points within the curvilinear grid before and after straightening for OUs 3 and 4.

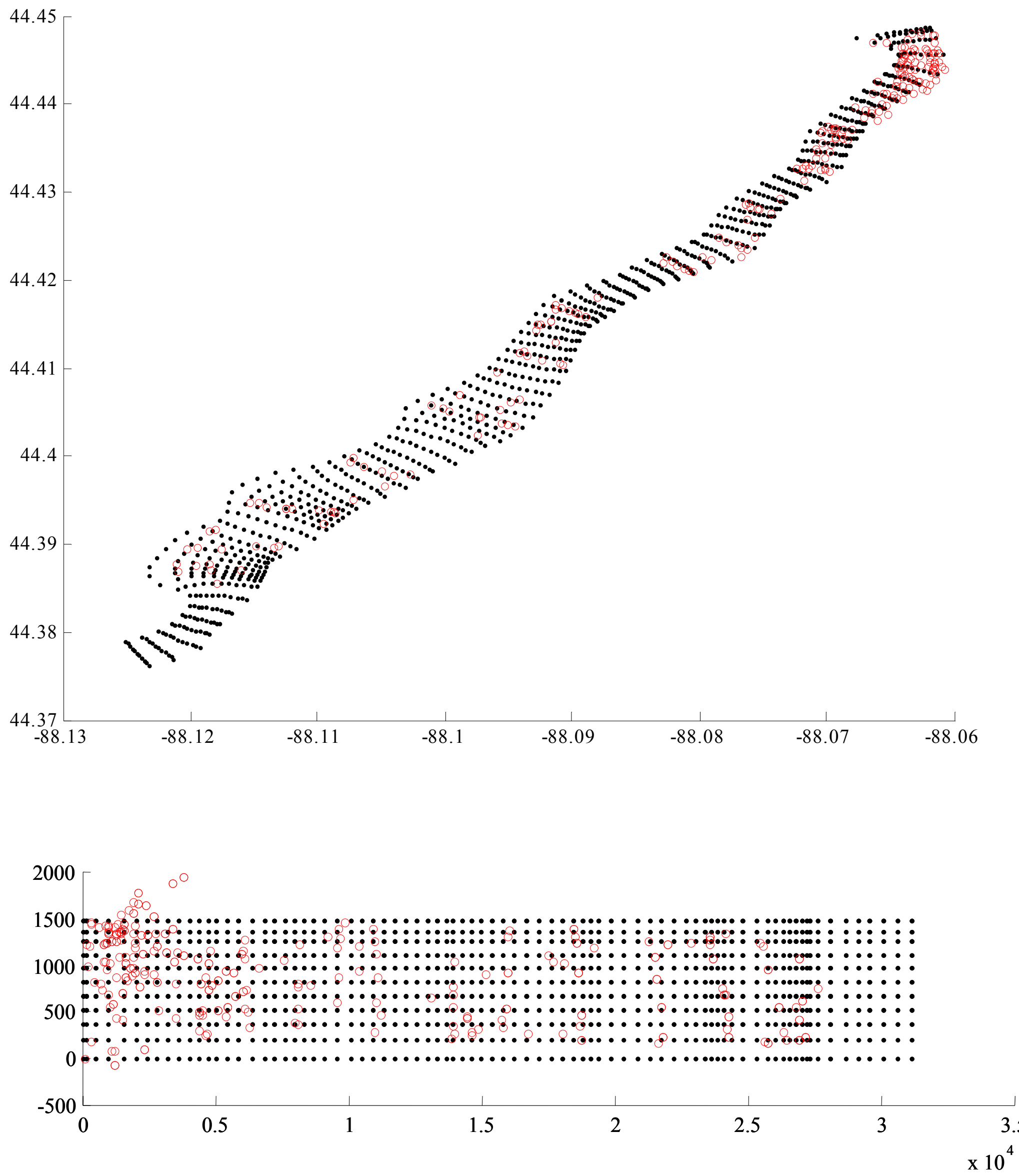


Figure A-1. Sample locations in OU 3 before and after straightening. Black dots are the nodes of the curvilinear grid, and red circles are sample locations. The lower left corner in the top graph corresponds to the top right corner on the bottom graph.

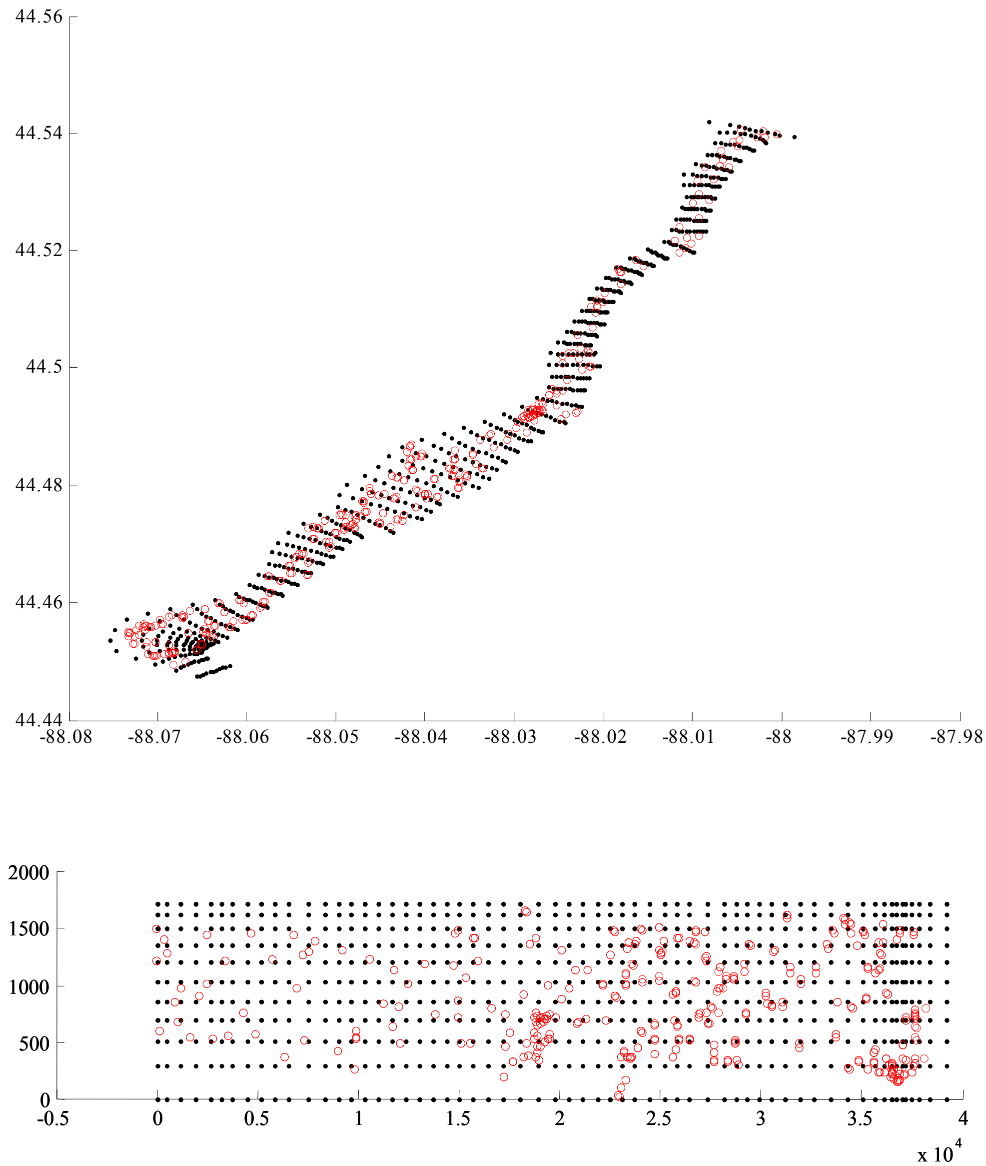


Figure A-2. Sample locations in OU 4 before and after straightening. Black dots are the nodes of the curvilinear grid, and red circles are sample locations. The lower left corner in the top graph corresponds to the top right corner on the bottom graph.

The semivariogram was calculated using the new coordinate system, and the range parameter was interpreted by translating distance in straightened coordinates to distance in meters using the average width of the OU.

SEMIVARIOGRAM ANALYSIS

Maximum Subsurface Total PCB Concentrations. Semivariograms were calculated for the four OUs described above. Figures A-3 through A-5 show the semivariograms for these OUs. The models for the two different directions are required to have the same nugget effect that is taken as the minimum among the two directions.

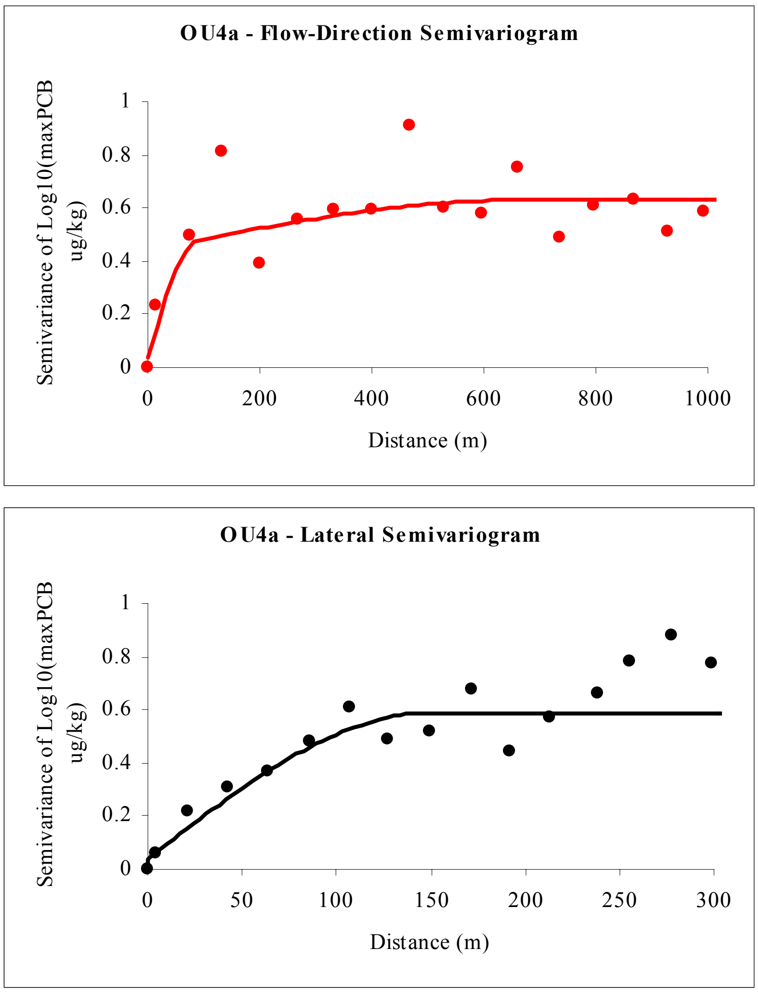


Figure A-3. Flow-direction and lateral semivariograms for OU 4a. Dots represent the values along the experimental semivariogram, the line represents the model.

OU 4a yielded semivariograms (shown above in Figure A-3) with a well-defined spatial structure (i.e., low nugget effect and a gradual rise over a well-defined range in both directions) as well as least noise and tighter fit of the data. The model is a so-called spherical model: *semivariance = sill * [1.5h/range – 0.5(h/range)3]*, where *h* is the separation distance. Spherical models are one among about 5 possible mathematical expressions for semivariogram models that are allowed in kriging. Spherical models are the most commonly used.

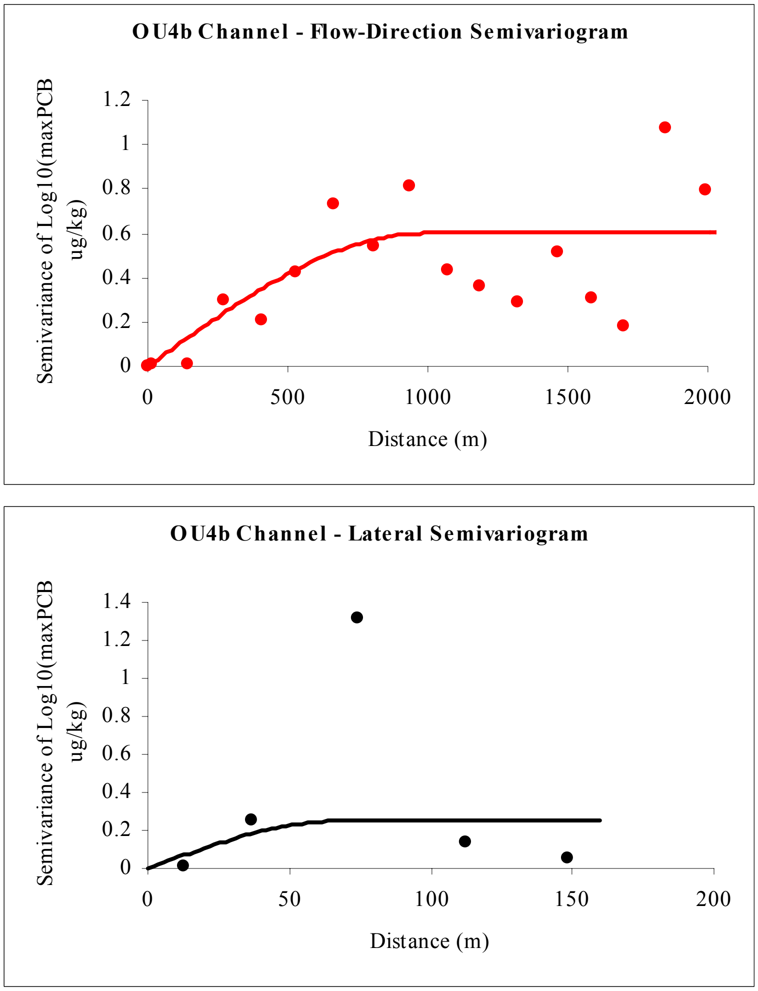


Figure A-4. Flow-direction and lateral semivariograms for OU 4b channel. Dots represent the values along the experimental semivariogram, the line represents the model.

For the dredged channel in OU 4b (shown above in Figure A-4), the semivariograms are more noisy, as indicated by the higher "scatter" of semivariance values in the vertical direction. In particular the lateral semivariogram lacks structure, due to a small number of data pairs along the lateral direction.

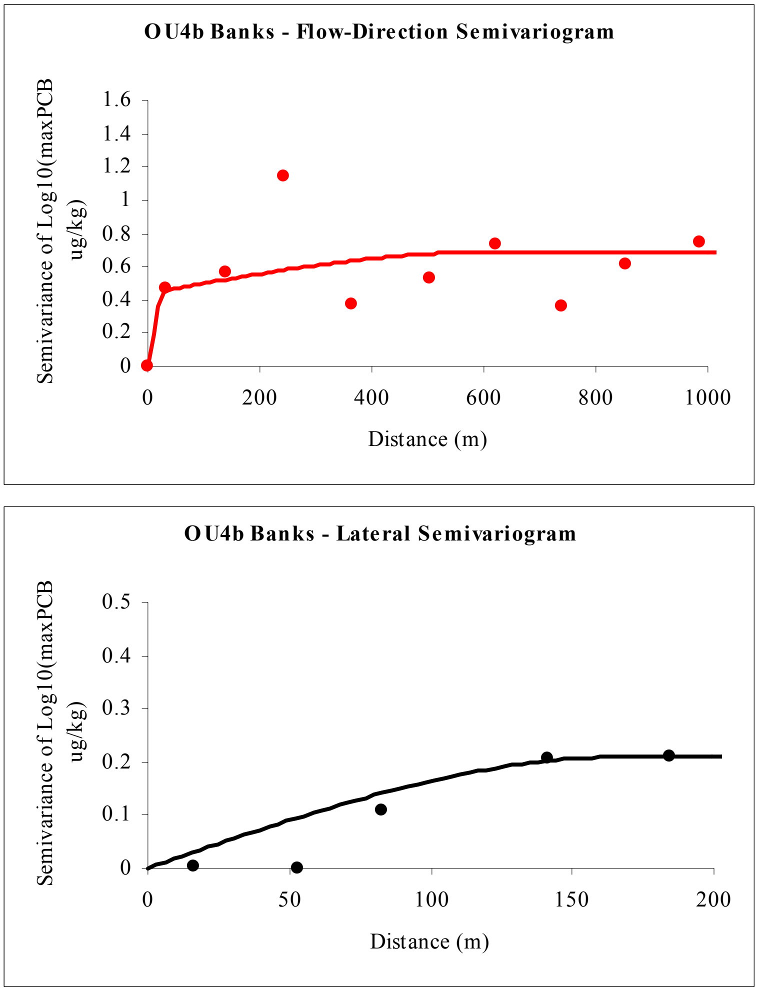


Figure A-5. Flow-direction and lateral semivariograms for OU 4b near banks. Dots represent the values along the experimental semivariogram, the line represents the model.

For data in OU 4b between the dredged channel and the banks (shown above in Figure A-5), semivariograms are also more noisy than for OU 4a. The lateral semivariogram is somewhat better defined than for OU 4b channel, indicating a greater number of paired data along the lateral direction.

In OU 3, correlation structures are obscured by a more sparse distribution of sampling points and by inconsistencies among the various sampling investigations that used different field and analytical methods. Nevertheless, preliminary indications of correlation scales in the data from OU 3 are consistent with those observed in OU 4a.

As a result of higher sampling density, better defined correlation structures, and indications of similar structures in adjacent reaches of the river, the spatial correlation structures determined for OU 4a were assumed to be representative of conditions in OU 3 and OU 4b.

Surficial Total PCB Concentrations. Semivariograms were also calculated for surface sediments within OU 4a as a whole, and for sediment management units (SMUs) 26-60 (i.e., excluding SMUs 21 -25 which are subject to anomalous hydrodynamics in the discharge zone below the De Pere Dam). Figure A-7 and A-8 show the semivariograms for these OUs. The semivariograms are consistent with the results for maximum total PCBs in the subsurface of OU 4a. For simplicity, the coordinates were not transformed for this analysis.

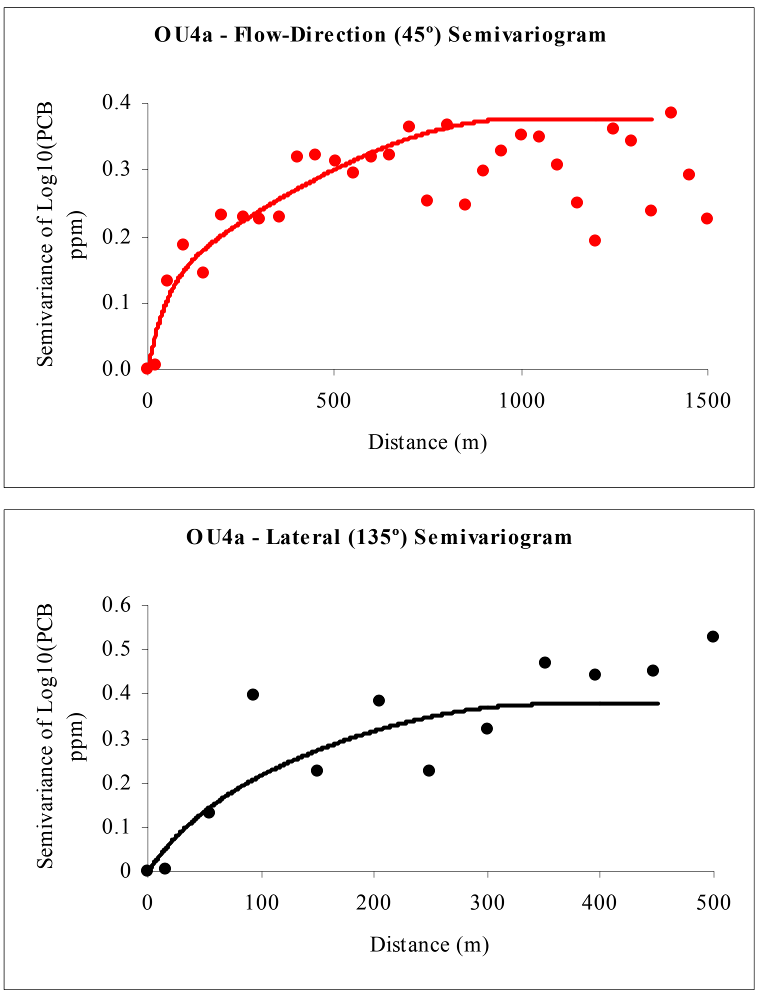


Figure A-7. Flow-direction and lateral semivariograms for OU 4a as a whole. Dots represent the values along the experimental semivariogram, the line represents the model.

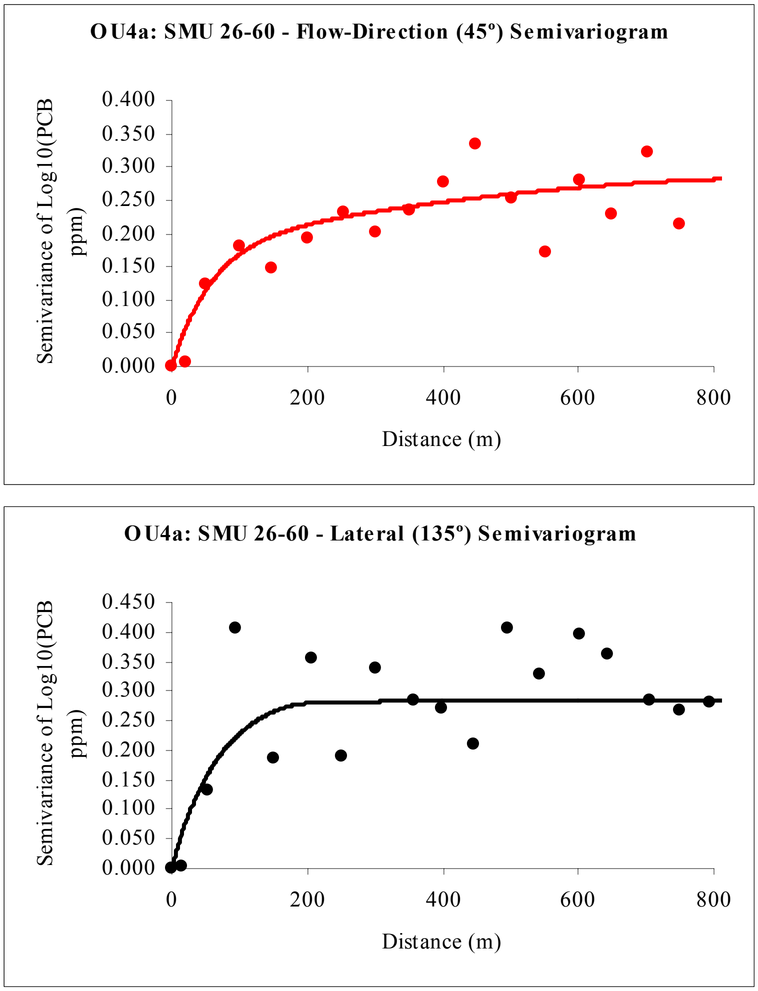


Figure A-8. Flow-direction and lateral semivariograms for OU 4a: SMUs 26-60. Dots represent the values along the experimental semivariogram, the line represents the model.

CORRELATION SCALES AND SAMPLE GRID SPACINGS

A summary of correlation scales in the unmaintained (undredged) section of OU 4 is provided in the table below.

Location	95% Range Transverse (meters)	95% Range Longitudinal (meters)	100% Range Transverse (meters)	100% Range Longitudinal (meters)
SMU 20-60 Surface	270	400	350	1,000
SMU 26-60 Surface	160	600	200	900
SMU 20 to 60 Subsurface	125	400	150	670

Based on the semivariogram analysis, a reasonable average correlation scale for OU 3 and OU 4 is 200 m (660 ft) in the transverse direction, and 500 meters (1,640 ft) in the longitudinal direction. Sample grids based on one-half the distance of the correlation scale are appropriate (Caeiro et al. 2003) and will be applied to Category B and D areas (see Section 3.1.1.1 of the Work Plan). A higher density sampling grid, based on one-quarter the distance of the correlation scale will be applied to Category A and C areas, where careful delineation of the 1-ppm RAL and 50-ppm TSCA criterion are required. Sample grid spacings are summarized in the table below.

Location	Transverse Range (meters)	Longitudinal Range (meters)	Transverse Range (feet)	Longitudinal Range (feet)	Area per Core (acres)
Average Correlation Scale	200	500	660	1,640	N/A
Grid Spacing – Category B & D	100	250	330	820	6.2
Grid Spacing – Category A & C	50	125	165	410	1.6

In addition to determining grid spacings that will ensure good inter-sample correlation, grid spacings may be locally adjusted based on a qualitative review of the recently collected sub-bottom profiling data when it is available. If areas of complex sub-bottom structures are observed which may influence PCB accumulations in the overlying sediment (for example, channelization of the native contact surface), additional cores may be added to characterize these complex areas. On the other hand, grid spacings may be expanded in areas of relatively uniform and horizontal stratigraphy.

Kriging Analysis. The process of kriging uses the semivariograms to find the semivariance value associated for a particular separation distance between an estimation location and a data point in the vicinity. This semivariance is used in an equation to calculate the weight applied in the linear combination of data points yielding the estimated concentration at a location where no measurements have been taken.

The results of the correlation analysis (correlation range and model structure) were input to a geostatistical data analysis package to develop kriging estimates of maximum subsurface PCB concentrations, as shown in Figure 2-9 of the Work Plan. The longitudinal axis of the kriging model was aligned parallel with the average river flow direction—28 degrees (NNE) in OU 4 and 32 degrees (NNE) in OU 3. The sill value of the kriging model was not explicitly specified, but was implicitly calculated by the geostatistics software and was consistent with the overall population variance of the data.

For additional information on kriging theory and application, the reader is referred to Isaaks and Srivastava, 1989.

This appendix was written by Limno-Tech, Inc., March 2004.

APPENDIX B – CONTINGENT CAPPING REMEDY EVALUATION

B.1 Contingent Capping Remedy Evaluation

In situ capping is defined as the placement of an engineered covering (or cap) over an in situ deposit of contaminated sediment. In situ caps generally consist of a layer of clean granular materials, such as sediment, sand, or gravel. In situ caps may incorporate multiple layers of materials including geotextiles and impermeable liners. Capping of subaqueous contaminated sediments is an accepted engineering option for managing dredged materials and for in situ remediation of contaminated sediments (USEPA, 1994, 2002; NRC, 1997, 2001; Palermo et al., 1998a, 1998b) and has been successfully implemented at numerous sites under varying conditions.

In situ caps may remedy some or all of the adverse impacts associated with contaminated sediments through three primary functions:

- Physical isolation of the contaminated sediment from the aquatic environment;
- Stabilization/erosion protection of contaminated sediment, preventing resuspension and transport to other sites; and
- Chemical isolation/reduction of the movement of dissolved and colloidally transported contaminants.

This section presents a method for the evaluation of a contingent in situ capping remedy for OUs 3 and 4 of the Lower Fox River. A framework is presented for the comparative evaluation of the dredging remedy (the “selected” remedy from the ROD [WDNR and USEPA, 2003]) with an in situ capping remedy as well as with a contingency dredge/cap remedy using a set of criteria described below.

If an in situ capping remedy is determined to be feasible and meets the criteria described in the ROD, a technical evaluation will be submitted to the Response Agencies (WDNR and USEPA) for review and approval. Pending the subsequent development of an ESD by the Response Agencies, a remedial design will be completed and this contingency remedy may be implemented in conjunction with the selected dredging remedy.

This appendix provides a review of the RAOs and performance standards for cleanup of the Lower Fox River, as set forth in the ROD. A comparative evaluation framework is developed, which will be implemented in subsequent documentation to evaluate the feasibility and protectiveness of an in situ capping remedy as compared to the ROD-selected dredging remedy.

B.1.1 Remedial Action Objectives and Performance Criteria

B.1.1.1 Remedial Action Objectives

As presented in the ROD, five RAOs have been established for the Lower Fox River cleanup project including the following:

RAO 1: Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay. This RAO is intended to reduce PCB concentrations in surface water as quickly as possible. The current water quality criteria for PCBs are 0.003 μg/L for the protection of human health and 0.012 μg/L for the protection of wild and domestic animals. Water quality criteria incorporate all routes of exposure assuming the maximum amount is ingested daily over a person's lifetime.

RAO 2: Protect humans who consume fish from exposure to contaminants of concern (COC) that exceed protective levels. This RAO is intended to protect human health by targeting removal of fish consumption advisories as quickly as possible. The WDNR and USEPA defined the expectation for the protection of human health as the likelihood for recreational anglers and high-intake fish consumers to consume fish within 10 years and 30 years, respectively, at an acceptable level of risk or without restrictions following completion of a remedy.

RAO 3: Protect ecological receptors from exposure to COCs above protective levels. RAO 3 is intended to protect ecological receptors such as invertebrates, birds, fish, and mammals. The WDNR and USEPA defined the ecological expectation as the likelihood of achieving safe ecological thresholds for fish-eating birds and mammals within 30 years following remedy completion. Although the FS did not identify a specific time frame for evaluating ecological protection, the 30-year figure was used as a measurement tool.

RAO 4: Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan. The objective of this RAO is to reduce the transport of PCBs from the River into the Bay and Lake Michigan as quickly as possible. The WDNR and USEPA defined the transport expectation as a reduction in loading to the Bay and Lake Michigan to levels comparable to the loading from other Lake Michigan tributaries. This RAO applies only to River reaches.

RAO 5: Minimize the downstream movement of PCBs during implementation of the remedy. A remedy is to be completed within 10 years.

Table B-1 details how the RAOs for the Fox River could be achieved by an in situ capping remedy employed in conjunction with the selected remedy (dredging).

B.1.1.2 Performance Standards

Performance standards for remediation of OUs 2 through 5 of the Lower Fox River will be developed during remedial design, depending on the ESD determination. For the Lower Fox River, the performance/design criteria for capping will likely include the following (Palermo et al., 2002):

- Technical, regulatory and institutional issues would be appropriately considered in identifying potential areas for capping;
- The cap would be designed to provide physical isolation of the PCB-contaminated sediments from benthic organisms;
- The cap would be physically stable from scour by currents (river and propeller-induced), flood flow, and ice scour. The 100-year flood event would likely be considered in these evaluations;
- The cap would provide isolation of the PCB-contaminated sediments in perpetuity from flux or resuspension into the overlying surface waters. An appropriate surficial sediment concentration standard would apply as a construction standard to ensure the cap is initially placed as a clean layer, and would also apply as a long-term limit with respect to chemical isolation;
- The cap design would consider operational factors such as the potential for cap and sediment mixing during cap placement and variability in the placed cap thickness; and
- The cap design would incorporate an appropriate factor of safety to account for uncertainty in site conditions, sediment properties, and migration processes.

B.1.2 Comparative Evaluation Framework – Dredging and Capping Technologies

As stated in Sections 13.4 and 13.5 of the ROD, an in situ capping remedy may be implemented in conjunction with the selected dredging remedy provided the following can be shown:

- The capping remedy will provide the same level of protection of human health and the environment as the selected remedy (dredging) as evaluated in accordance with the protectiveness provisions and the nine evaluation criteria in the National Contingency Plan (NCP) (40 CFR 300.430(e)(9)).

- The capping remedy will be less costly to implement than the selected remedy.
- The capping remedy will not take more time to implement than the selected remedy.
- The capping remedy will comply with all necessary regulatory, administrative, and technical requirements.
- The capping remedy will be implemented in appropriate areas.

Section 11 of the ROD presented the results of a comparative evaluation of nine remedial alternatives, including dredging alone and combined dredging and in situ capping, using the nine NCP evaluation criteria. The evaluation in the ROD consisted of an assessment of each individual alternative to against each of the nine evaluation criteria. In addition, the ROD presented a general comparative analysis focusing on the performance of each alternative against those criteria. This work plan presents a framework to extend the comparative evaluation presented in the ROD through additional detail of several of the criteria, focusing on the three remedial alternatives listed below.

- Dredging with off-site disposal;
- In situ capping; and
- Dredging followed by in situ capping.

It should be noted that if in situ capping is determined feasible and approved in an ESD, it would only be implemented in appropriate areas, with dredging implemented in other areas.

The comparative evaluation framework presented in this work plan includes a consolidated list of nine NCP criteria for the purposes of addressing the ROD requirements, listed above, related to the contingent remedy (capping) in comparison to the selected remedy (dredging). The following criteria will be used in the comparative evaluation:

Threshold Criteria

- **Overall Protection of Human Health and the Environment.** This addresses whether the remedy provides adequate protection of human health and the environment and will describe how risks posed through each exposure pathway are eliminated, reduced, or controlled through treatment, engineering, or institutional controls.

- **Compliance with ARARs.** This addresses whether the remedy will meet applicable or relevant and appropriate federal and state environmental laws and/or justifies a waiver from such requirements.

Primary Balancing Criteria

- **Long-Term Effectiveness and Permanence.** This refers to expected residual risk and the ability of the remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met.
- **Reduction of Toxicity, Mobility, or Volume through Treatment.** This addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.
- **Short-Term Effectiveness.** This addresses the period of time needed to achieve protection and any adverse impacts on human health and the environment that may be posed until cleanup levels are achieved.
- **Implementability.** This addresses the technical and administrative feasibility of the remedy, including the availability of materials and services needed to implement a particular option.
- **Cost.** This includes estimated capital costs, annual operation and maintenance costs (assuming a 30-year time period), and net present value of capital and operation and maintenance costs, including long-term monitoring.

Modifying Criteria

- **Agency and Community Acceptance.** This considers whether the Response Agencies, in this instance the WDNR and USEPA, concur with the remedy selection and the analyses and recommendations of this work plan and subsequent ESD, if appropriate. Community acceptance addresses the public's general response to the remedial alternatives and proposed plan.

B.1.3 Method for Evaluating the In Situ Capping Remedy

B.1.3.1 Cap Design Guidance

Detailed guidance for in situ capping as a remedial alternative for contaminated sediment has been developed by USACE and USEPA. The documents *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2002), *Guidance for Subaqueous Dredged Material Capping* (Palermo et al., 1998a), and *Guidance for In Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al., 1998b), provide detailed procedures for site and sediment characterization, cap design, cap placement operations, and monitoring for subaqueous capping. These guidance documents, specifically Palermo et al. (1998b), serve as the technical basis for design-level evaluations of the contingent capping remedy, as outlined above.

These guidance documents recommend a generalized approach to designing an in situ cap, including considerations of specific design components, as summarized below:

- Identification of candidate capping locations based on site conditions and future use requirements;
- Assessment of the potential contaminant mobility from the sediment into the water column, and design of a cap component to prevent breakthrough within a given design life;
- Assessment of the bioturbation potential of local burrowing benthic organisms, and design a cap component to physically isolate them from contaminated sediment;
- Evaluation of the potential for erosion of the cap due to natural and anthropogenic disruptive forces and design of a cap component (or system) that will be stable or have acceptable losses under these conditions;
- Identification of candidate capping materials that are physically and chemically compatible;
- Evaluation of geotechnical considerations including consolidation of compressible materials (in situ or within the cap), slope stability, and seismic considerations (if applicable);
- Evaluation of construction and placement methods, and identification of performance objectives and monitoring methods for cap placement and long-term assessment;
- Assessment of the operational considerations and determination of restrictions or additional protective measures (e.g., institutional controls) needed to ensure cap integrity; and
- Assessment of the potential for long-term habitat alteration (e.g., changes in depth, substrate, and hydrodynamic regime) and mitigation design, if appropriate.

Figure B-1 is a flow chart showing the major steps in the evaluation and design of an in situ cap, which include the following:

- Set a cleanup objective, i.e., a contaminant concentration or other benchmark.
- Site characterization including physical properties, waterway uses, and information on geotechnical conditions.
- Characterize the contaminated sediments under consideration including the physical, chemical, and biological characteristics of the sediments.
- Make a preliminary determination on the feasibility of in situ capping based on information obtained about the site and sediments.
- Identify potential sources of capping materials.
- Design the cap composition and thickness consider the following:
    - Chemical isolation of contaminants,
    - Bioturbation,
    - Consolidation,
    - Erosion, and
    - Operational considerations (i.e., other pertinent processes).
- Select appropriate equipment and placement techniques for the capping materials.
- Evaluate if the capping design meets the cleanup objectives.
- Develop an appropriate monitoring and management program to include construction monitoring during cap placement and long-term monitoring following cap placement.
- Develop cost estimates for the project to include construction, monitoring and maintenance costs.

B.1.4 Comparative Evaluation of Dredging and Capping Technologies

Prior to initiating an ESD for the contingent capping remedy, a comparative evaluation will be completed of the selected dredging remedy with in situ capping. The comparative evaluation is aimed at determining whether in situ capping would meet the requirements of the ROD, as discussed in Section B.9.2 (protectiveness; cost; timing to implement; administrative and technical requirements; and location).

This section presents the methodology for assessing each of the criteria to be used in the comparative evaluation.

B.1.4.1 Evaluation Criteria

As presented in Section B.9.2, the comparative evaluation criteria will include the following:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost; and
- Response Agency and community acceptance.

Table B-2 presents a summary of some of the factors that will be considered in assessing the compliance of each remedy with these evaluation criteria.

B.1.4.2 Potentially Suitable Cap Placement Areas and Cap Specification

Potential capping areas were delineated in the DEA (Retec, 2003), with consideration of the following:

- Caps will not encumber federally authorized navigation channels or interfere with maintenance of the such channels (i.e., an appropriate buffer zone will be established);
- Caps will not be located where PCB concentrations exceed TSCA levels (50 ppm);
- Caps will not be located in areas where the post-placement water depth will be less than 3 feet; and
- Capping may avoid areas of infrastructure such as submerged pipelines, utility easements, bridge piers, etc.

In addition, the in situ cap design will consider the following:

- Caps will have a sufficient thickness to provide erosion protection, consistent with "*Guidance for In situ Subaqueous Capping of Contaminated Sediments*" (Palermo et al., 1998b); and

If practicable, caps will be designed to provide a surface that promotes colonization by aquatic organisms and/or fishery enhancement.

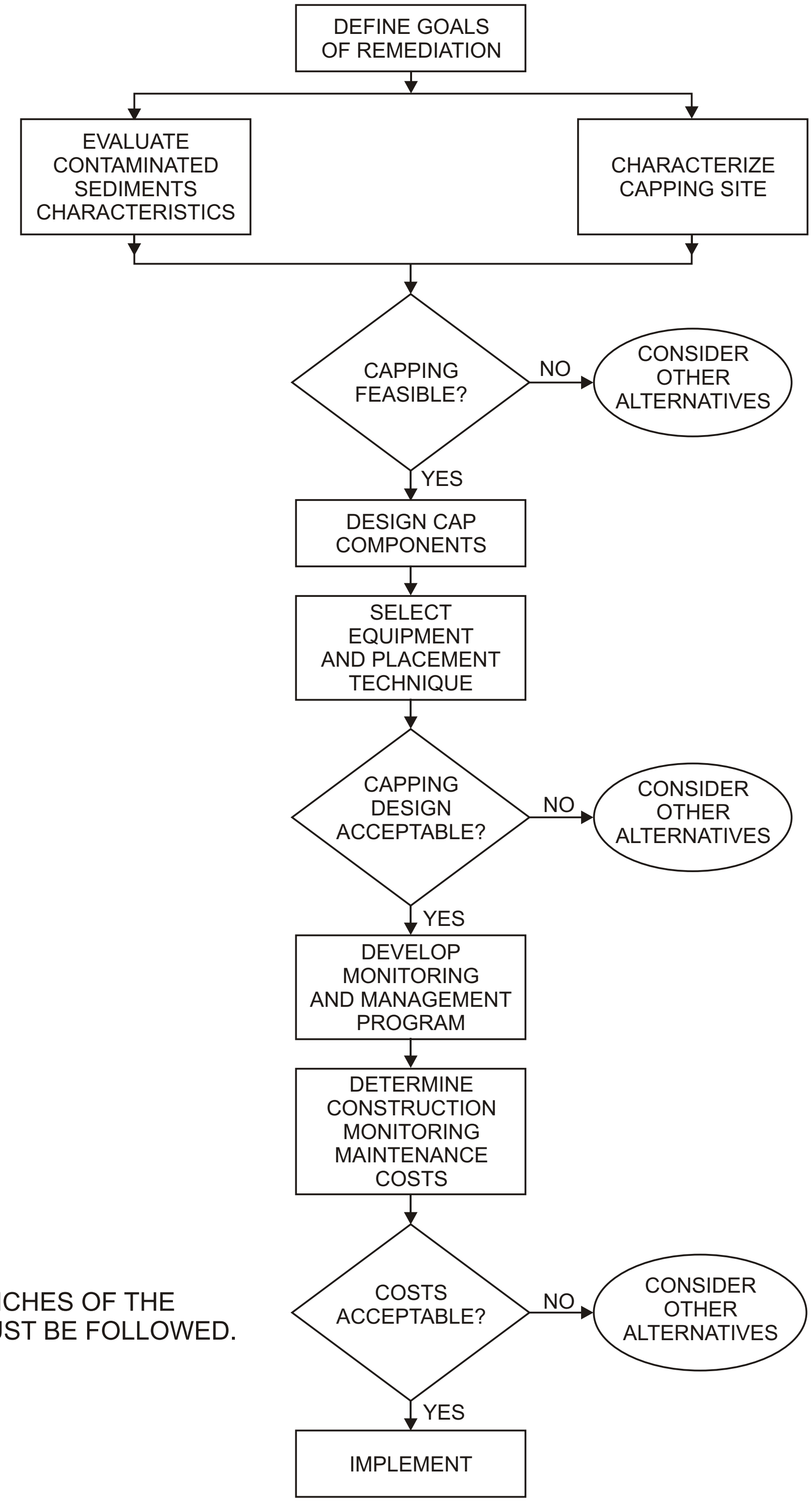
Table B-1. RAOs Potentially Met with In-Situ Capping

Remedial Action Objective (RAO)		In-Situ Cap Function that Meets RAO
1	Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay.	Chemical isolation/reduction prevents movement of dissolved and colloidally transported contaminants.
2	Protect humans who consume fish from exposure to COCs that exceed protective levels.	Cap provides long-term physical isolation of the contaminated sediment from the aquatic environment. This protection advances up the food chain to protect humans who consume fish.
3	Protect ecological receptors from exposure to COCs above protective levels.	Cap prevents bioaccumulation of contaminants by providing long-term physical isolation of the contaminated sediment from the aquatic environment.
4	Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan.	Cap provides stabilization/erosion protection of contaminated sediment, preventing resuspension and transport to other sites. Also cap provides chemical isolation/reduction preventing dissolved contaminant flux into surface water.
5	Minimize downstream movement of PCBs during implementation.	Resuspension of bottom sediments is relatively low during controlled cap placement compared to environmental removal options.

Table B-2. Comparative Evaluation Considerations

Criteria	Selected Remedy (Dredging with Offsite Disposal)	Dredging/In-Situ Capping	In-Situ Capping
Protection of Human Health and the Environment	Prediction of SWAC following removal of contaminated sediment exceeding RAL	EPA/Corps Guidance to predict contaminant migration through cap and comparison with 0.25 ppm PCB concentration performance standard	EPA/Corps Guidance to predict contaminant migration through cap and comparison with 0.25 ppm PCB concentration performance standard
Compliance with ARARS	Review of WAC (including NR 100, 200, 300, and 500 series), Code of Federal Regulations (CFR), and Wisconsin DOT (for transporation components)	Review of Wisconsin Statues (Chapter 30), Section 10 of U.S. Rivers and Harbors Act of 1899 (22 CFR 403) and Wisconsin Administrative Code (Chapter 116)	Review of Wisconsin Statues (Chapter 30), U.S. Rivers and Harbors Act of 1899 (22 CFR 403) and Wisconsin Administrative Code (Chapter 116)
Long-Term Effectiveness	Evaluation of effects of surface residuals after dredging	USACOE/EPA cap design guidance using existing sediment properties	USACOE/EPA cap design guidance using properties of sediment exposed by dredging
Reduction of Toxicity, Mobility, or Volume through Treatment	Toxicity is not destroyed, but mobility is reduced through appropriate controls at disposal site, which will be evaluated	USACOE/EPA cap design guidance for evaluation of reduction in contaminant mobility through application of chemical isolation component	USACOE/EPA cap design guidance for evaluation of reduction in contaminant mobility through application of chemical isolation component
Short-Term Effectiveness	Evaluation of short-term water quality impacts caused by dredging through predictive models and review of previous construction monitoring of similar projects	Evaluation of short-term water quality impacts caused by cap placement through review of previously completed construction monitoring for similar projects	Evaluation of short-term water quality impacts caused by cap placement through review of previously completed construction monitoring for similar projects
Cost	Review of cost estimate from ROD and DEA	Review of cost estimate from ROD and DEA	Review of cost estimate from DEA
Implementability	Review of local equipment availability and site conditions for use.	Review of local equipment availability and site conditions for use.	Review of local equipment availability and site conditions for use.
Agency and Community Acceptance	Currently selected remedy of ROD	Upon determination of feasibility, ESD would be submitted for comment and approval	Upon determination of feasibility, ESD would be submitted for comment and approval

DESIGN SEQUENCE FOR IN-SITU CAPPING PROJECTS



NOTE: ALL BRANCHES OF THE FLOWCHART MUST BE FOLLOWED.

Source: Palmero et al. 1998b

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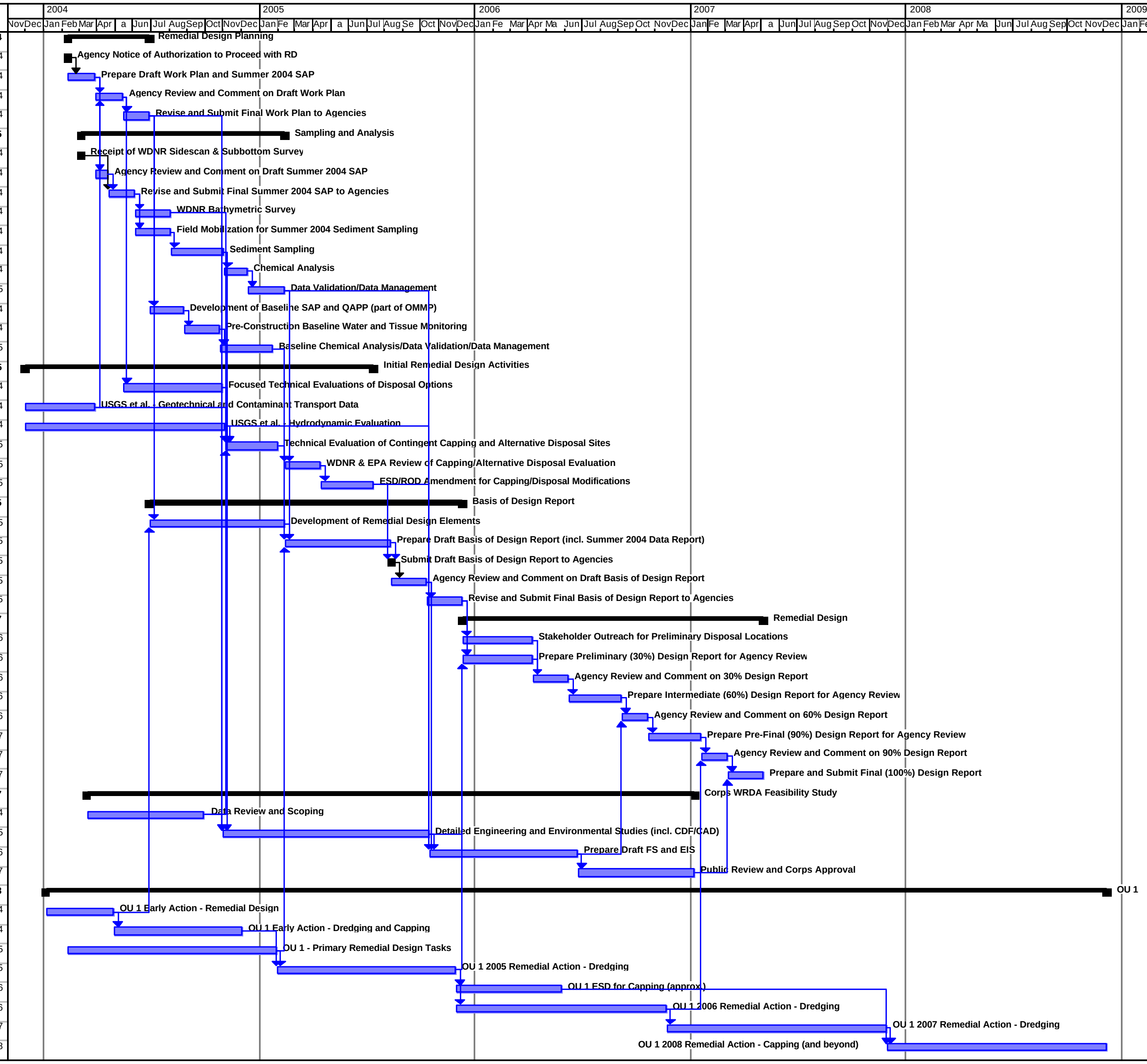
Figure B-1
In-Situ Capping Design and Evaluation Flow Chart
Lower Fox River

Figure 5-1. Fox River OU 2 through 5 Initial Remedial Design Schedule - March 31, 2004 Update

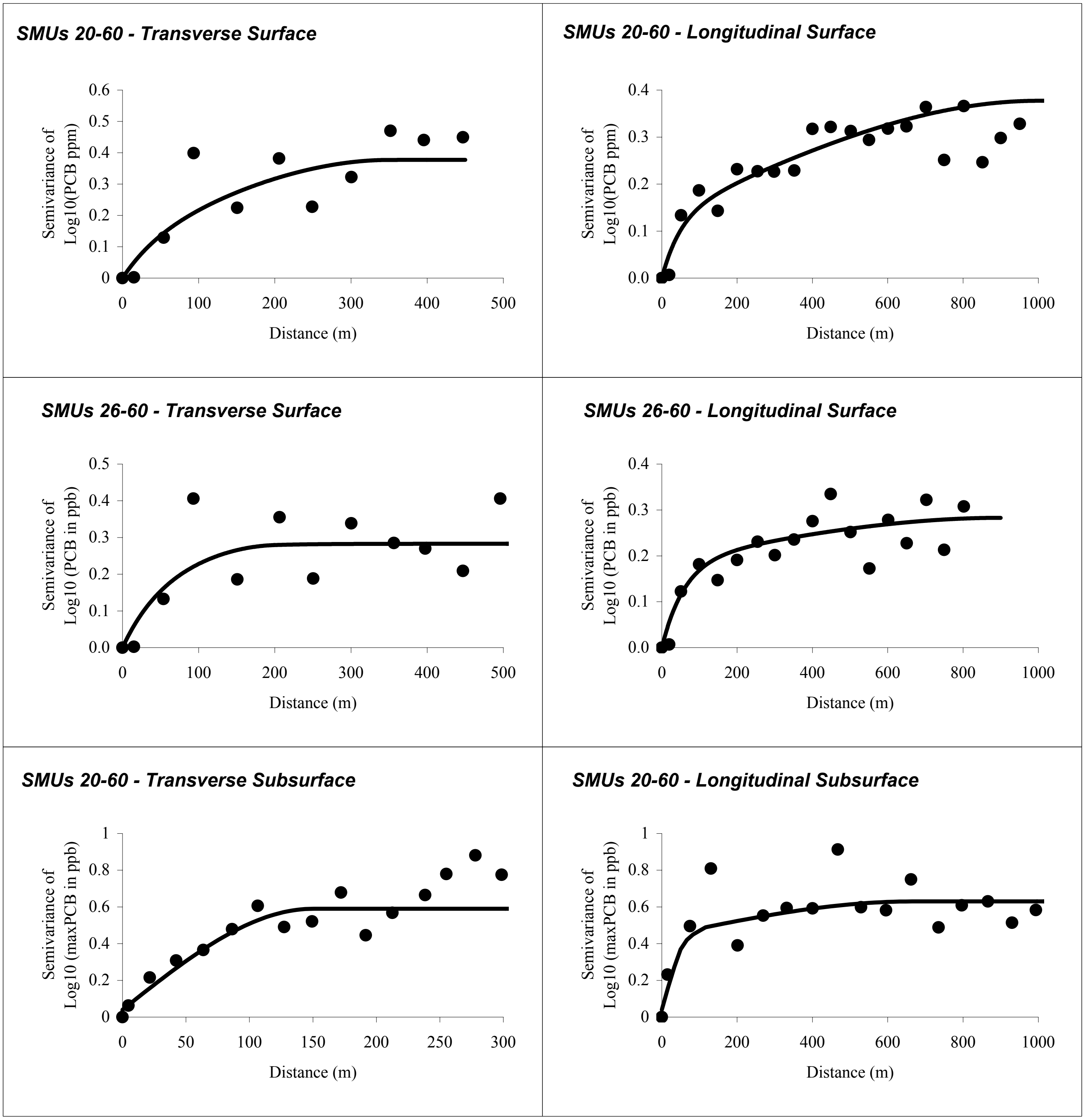
ID	Task Name	Finish
1	**Remedial Design Planning**	**Tue 6/29/04**
2	Agency Notice of Authorization to Proceed with RD	Fri 2/13/04
3	Prepare Draft Work Plan and Summer 2004 SAP	Wed 3/31/04
4	Agency Review and Comment on Draft Work Plan	Sat 5/15/04
5	Revise and Submit Final Work Plan to Agencies	Tue 6/29/04
6	**Sampling and Analysis**	**Mon 2/14/05**
7	Receipt of WDNR Sidescan & Subbottom Survey	Fri 3/5/04
8	Agency Review and Comment on Draft Summer 2004 SAP	Wed 4/21/04
9	Revise and Submit Final Summer 2004 SAP to Agencies	Sat 6/5/04
10	WDNR Bathymetric Survey	Wed 8/4/04
11	Field Mobilization for Summer 2004 Sediment Sampling	Wed 8/4/04
12	Sediment Sampling	Tue 11/2/04
13	Chemical Analysis	Tue 12/14/04
14	Data Validation/Data Management	Mon 2/14/05
15	Development of Baseline SAP and QAPP (part of OMMP)	Sat 8/28/04
16	Pre-Construction Baseline Water and Tissue Monitoring	Wed 10/27/04
17	Baseline Chemical Analysis/Data Validation/Data Management	Tue 1/25/05
18	**Initial Remedial Design Activities**	**Thu 7/14/05**
19	Focused Technical Evaluations of Disposal Options	Mon 11/1/04
20	USGS et al. - Geotechnical and Contaminant Transport Data	Tue 3/30/04
21	USGS et al. - Hydrodynamic Evaluation	Fri 11/5/04
22	Technical Evaluation of Contingent Capping and Alternative Disp	Thu 2/3/05
23	WDNR & EPA Review of Capping/Alternative Disposal Evaluation	Fri 4/15/05
24	ESD/ROD Amendment for Capping/Disposal Modifications	Thu 7/14/05
25	**Basis of Design Report**	**Sun 12/11/05**
26	Development of Remedial Design Elements	Mon 2/14/05
27	Prepare Draft Basis of Design Report (incl. Summer 2004 Data Re	Sat 8/13/05
28	Submit Draft Basis of Design Report to Agencies	Sat 8/13/05
29	Agency Review and Comment on Draft Basis of Design Report	Wed 10/12/05
30	Revise and Submit Final Basis of Design Report to Agencies	Sun 12/11/05
31	**Remedial Design**	**Sat 5/5/07**
32	Stakeholder Outreach for Preliminary Disposal Locations	Mon 4/10/06
33	Prepare Preliminary (30%) Design Report for Agency Review	Mon 4/10/06
34	Agency Review and Comment on 30% Design Report	Fri 6/9/06
35	Prepare Intermediate (60%) Design Report for Agency Review	Thu 9/7/06
36	Agency Review and Comment on 60% Design Report	Sun 10/22/06
37	Prepare Pre-Final (90%) Design Report for Agency Review	Sat 1/20/07
38	Agency Review and Comment on 90% Design Report	Tue 3/6/07
39	Prepare and Submit Final (100%) Design Report	Sat 5/5/07
40	**Corps WRDA Feasibility Study**	**Wed 1/10/07**
41	Data Review and Scoping	Fri 10/1/04
42	Detailed Engineering and Environmental Studies (incl. CDF/CAD)	Mon 10/17/05
43	Prepare Draft FS and EIS	Sat 6/24/06
44	Public Review and Corps Approval	Wed 1/10/07
45	**OU 1**	**Sun 12/7/08**
46	OU 1 Early Action - Remedial Design	Fri 4/30/04
47	OU 1 Early Action - Dredging and Capping	Fri 12/3/04
48	OU 1 - Primary Remedial Design Tasks	Mon 1/31/05
49	OU 1 2005 Remedial Action - Dredging	Wed 11/30/05
50	OU 1 ESD for Capping (approx.)	Mon 5/29/06
51	OU 1 2006 Remedial Action - Dredging	Wed 11/22/06
52	OU 1 2007 Remedial Action - Dredging	Fri 11/30/07
53	OU 1 2008 Remedial Action - Capping (and beyond)	Sun 12/7/08



Project: Figure 5-1 Fox River RD Sche
Date: Mon 3/29/04

Task | Split | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Split | Rolled Up Milestone | Rolled Up Progress | External Tasks | Project Summary | External Milestone | Deadline

Figure 3-1. Semivariogram Analysis of Surface and Subsurface Sediments



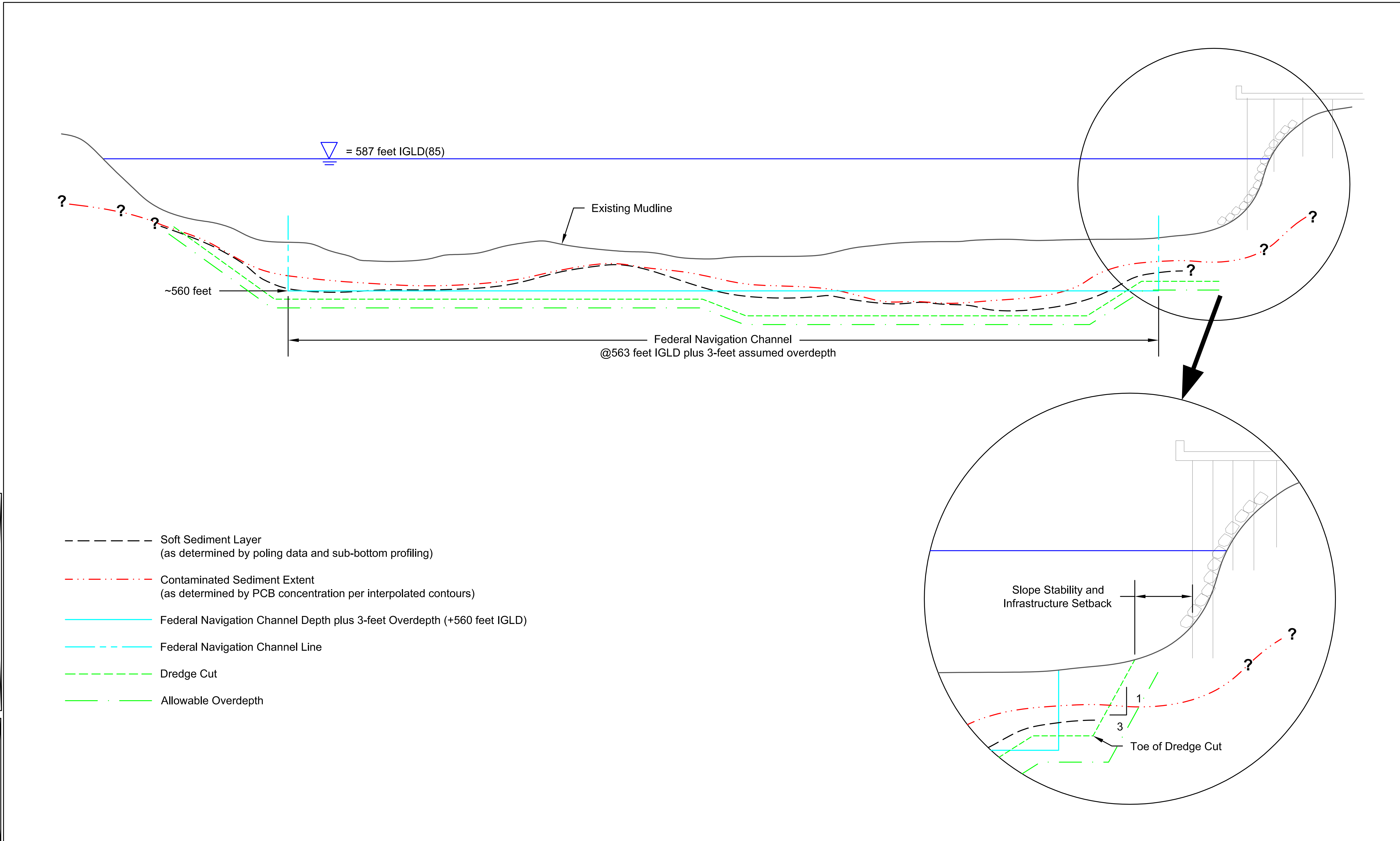


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Figure 2-16
LOWER FOX RIVER CONCEPTUAL
CROSS SECTION AND
DREDGE PLAN

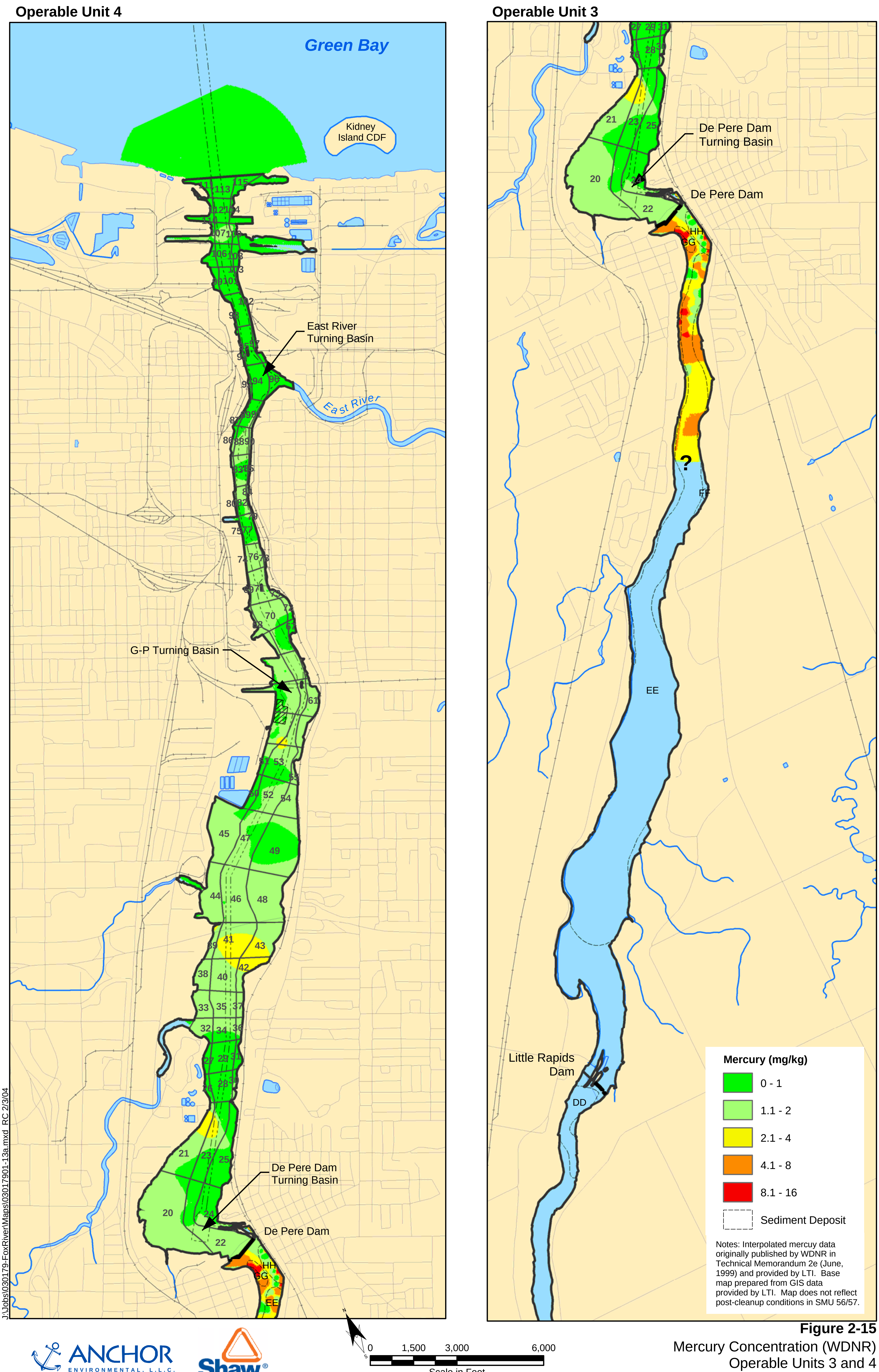
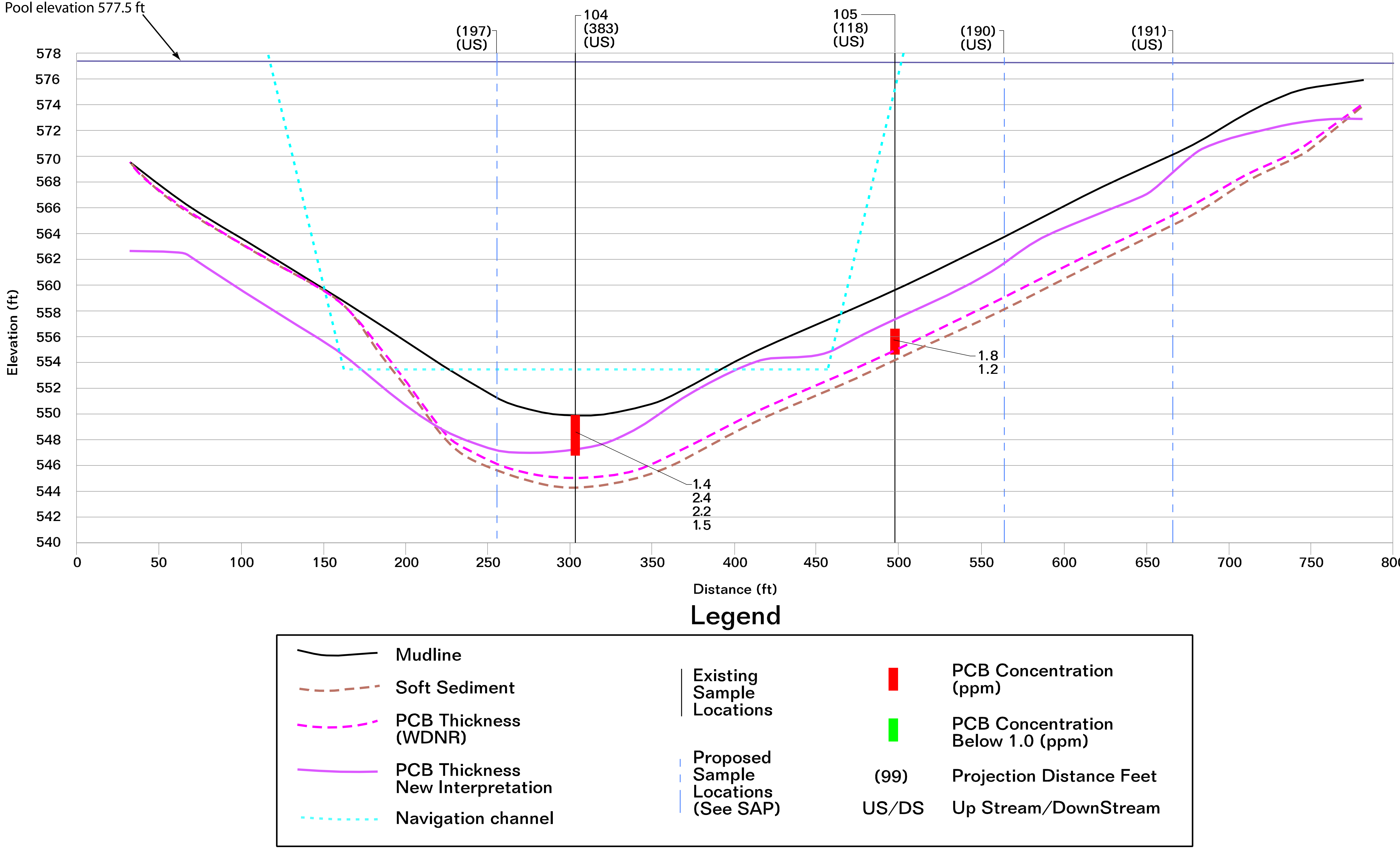
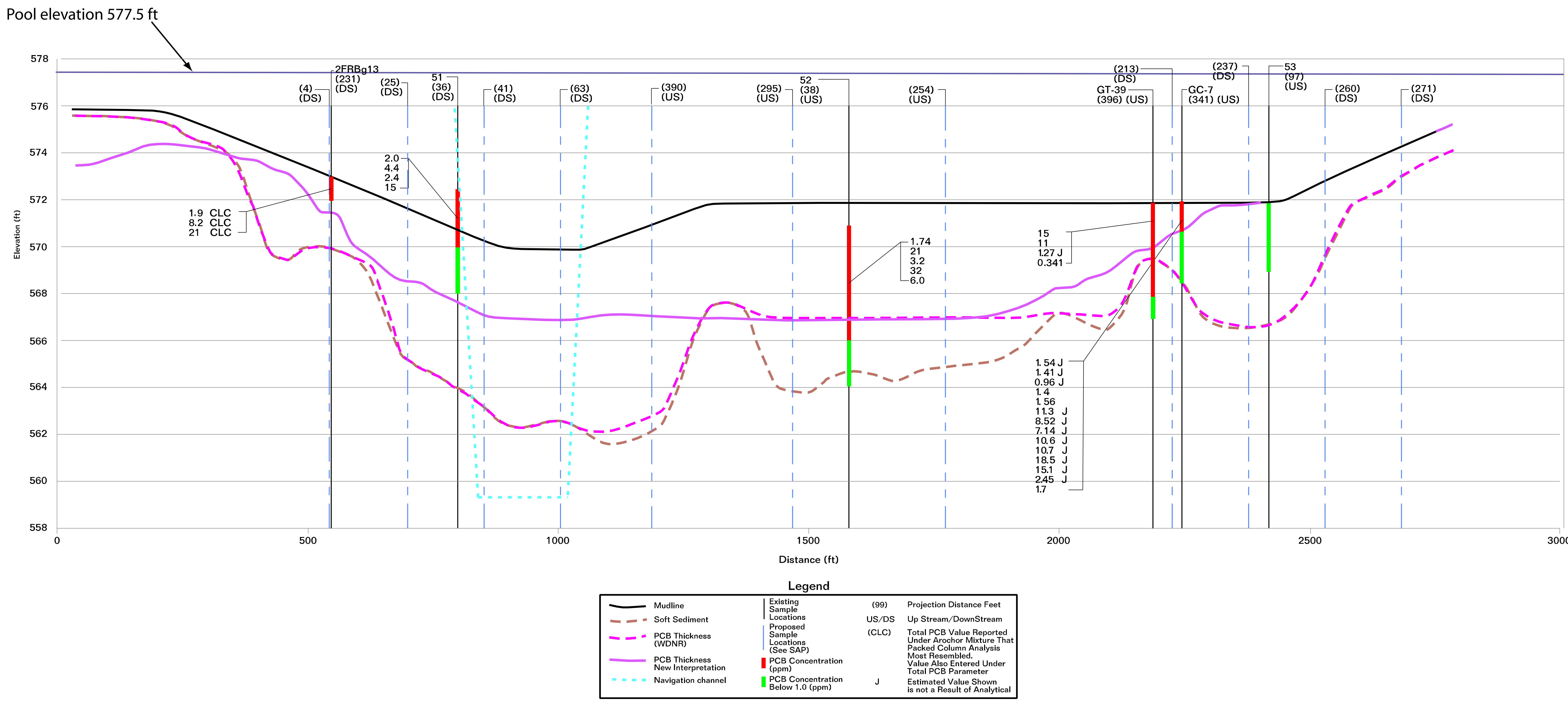


Figure 2-15
Mercury Concentration (WDNR)
Operable Units 3 and 4
Lower Fox River



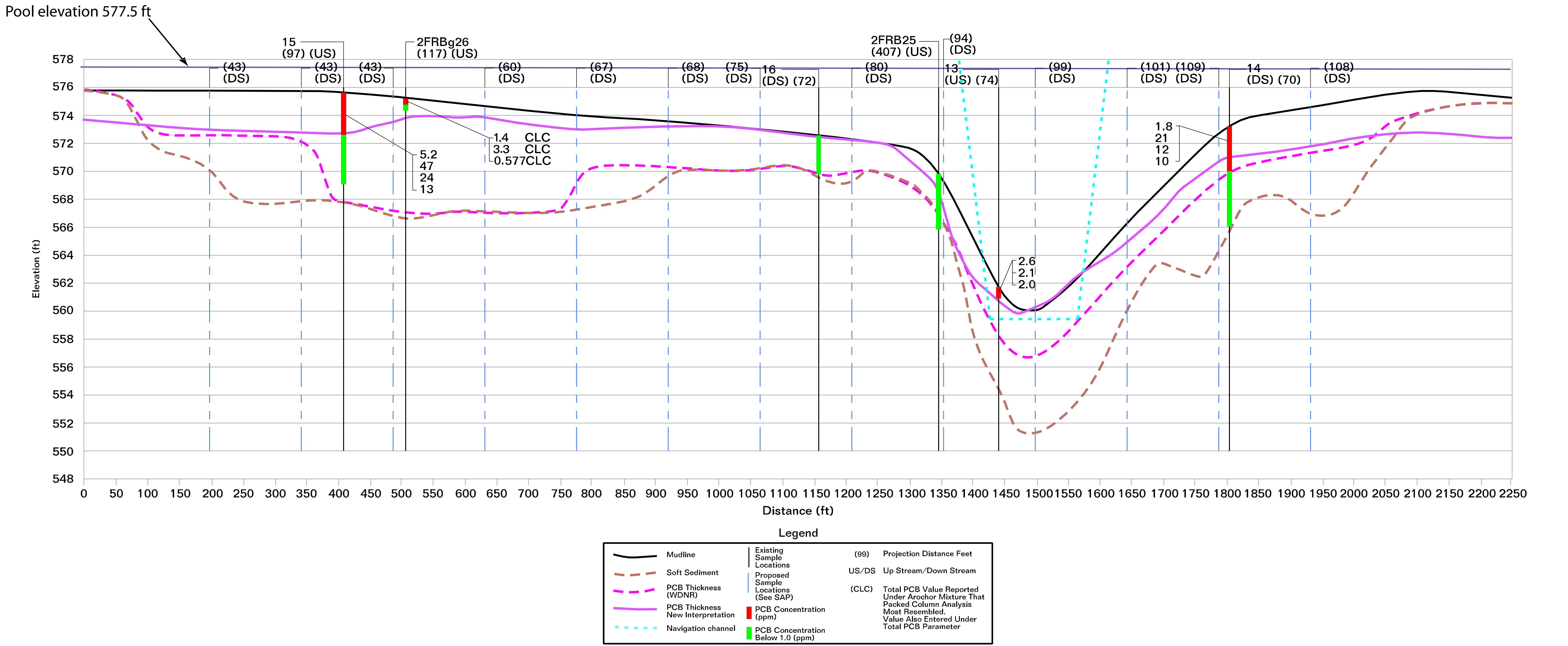
Cross Section F - OU 4 Mouth of Lower Fox River

Figure 2-14 Sheet 3

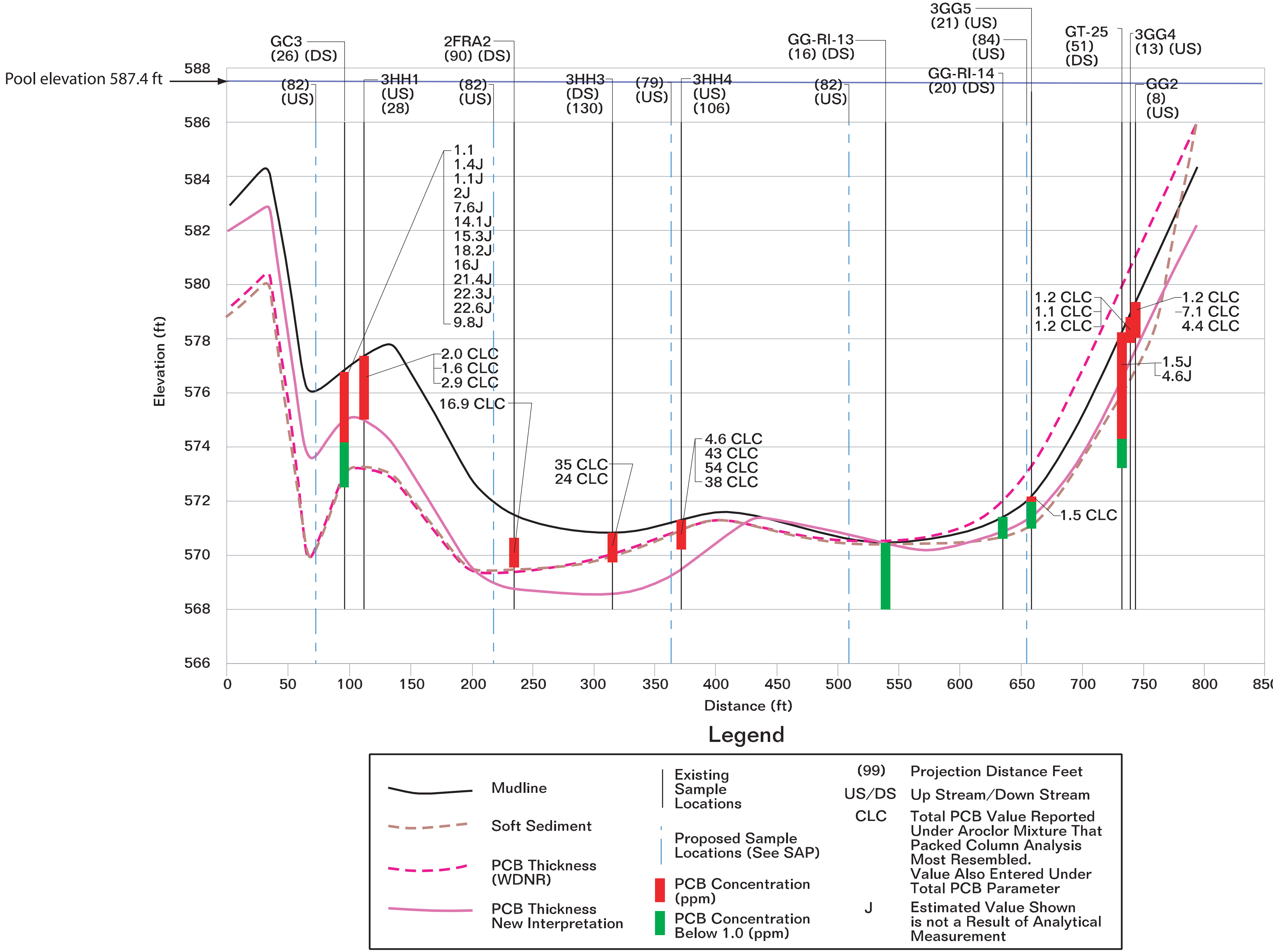


Cross Section E - OU 4 Mid Reach

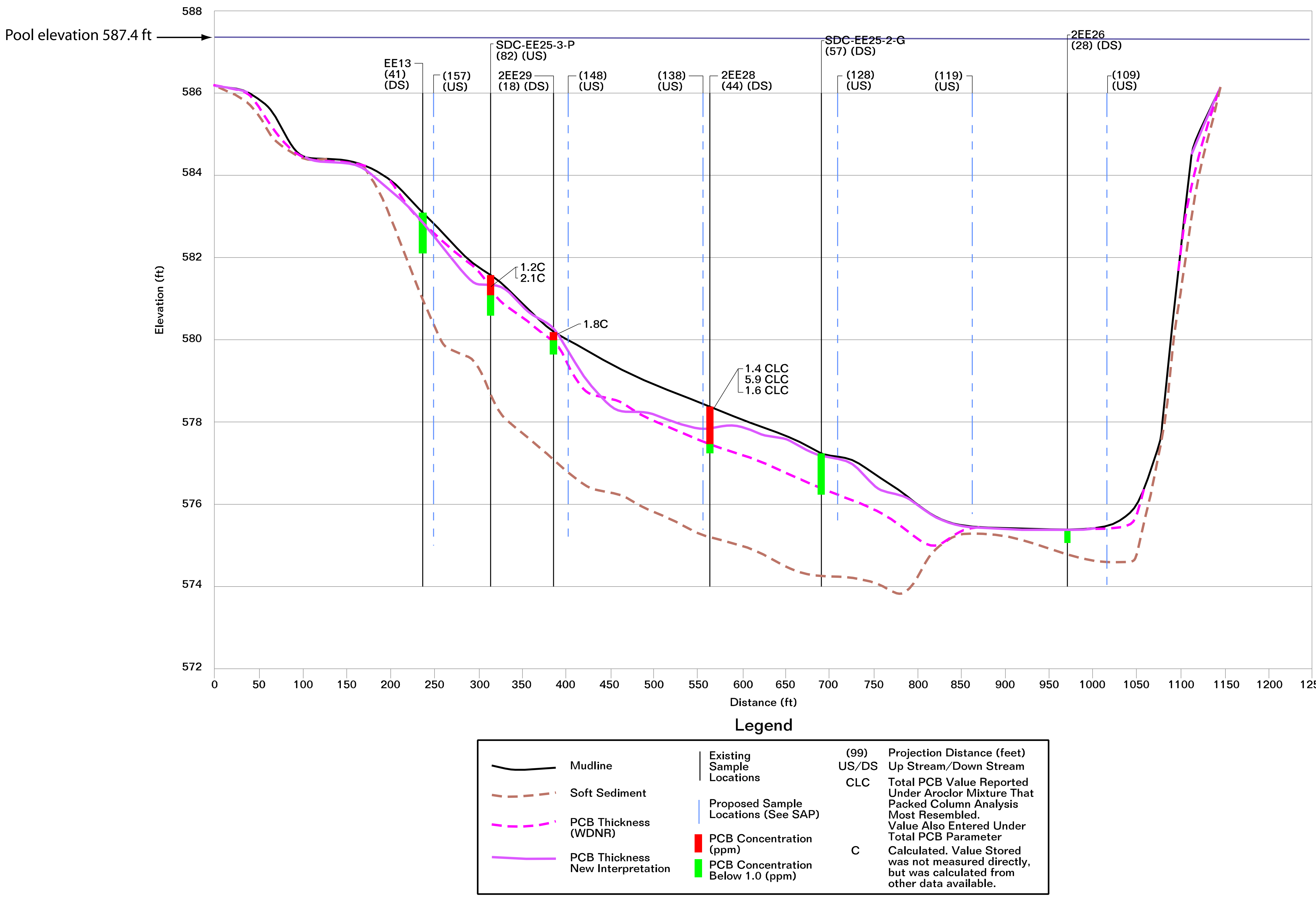
Figure 2-14 Sheet 2



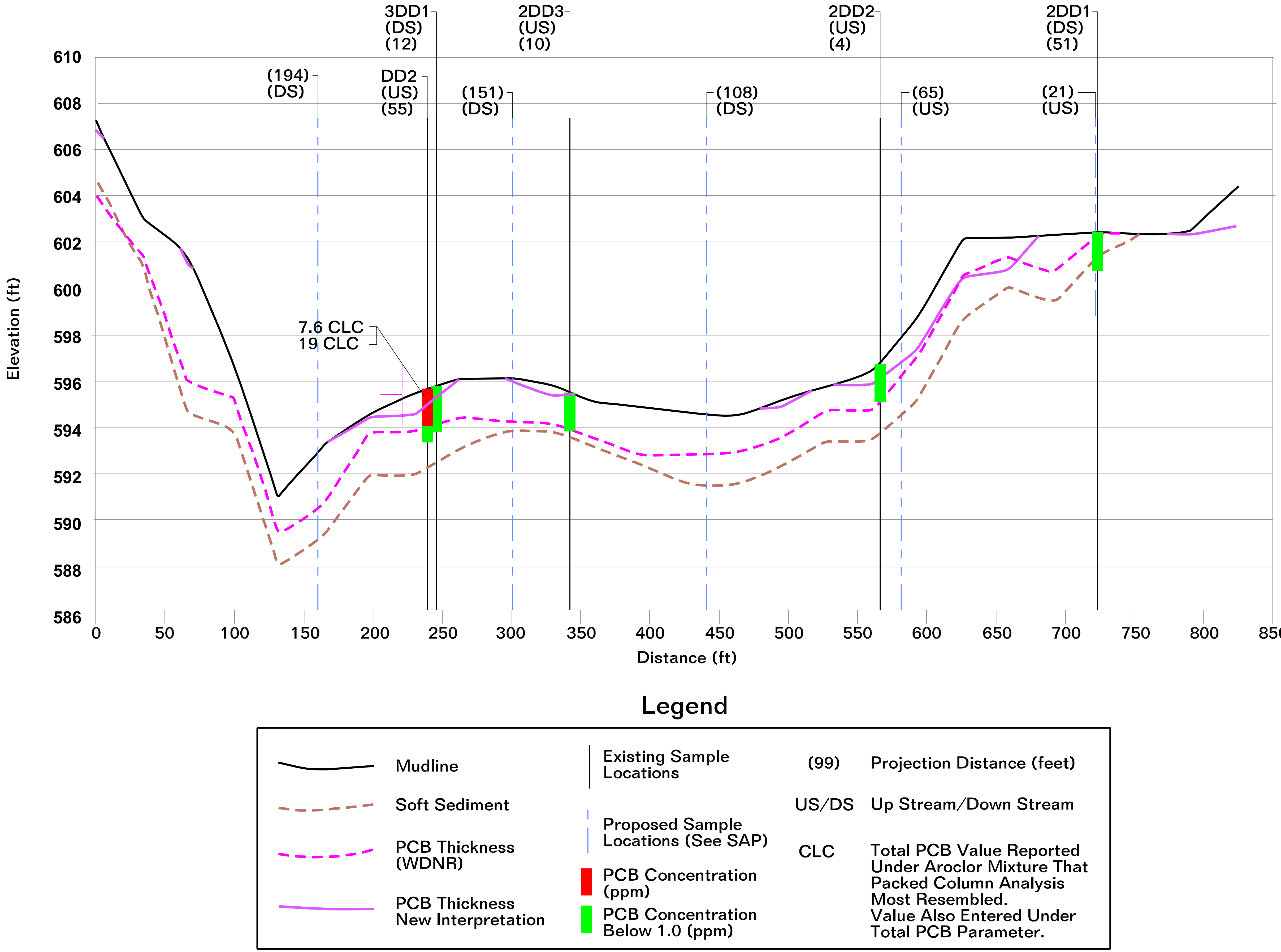
Cross Section D - OU 4 Below De Pere Dam
Figure 2-14 Sheet 1



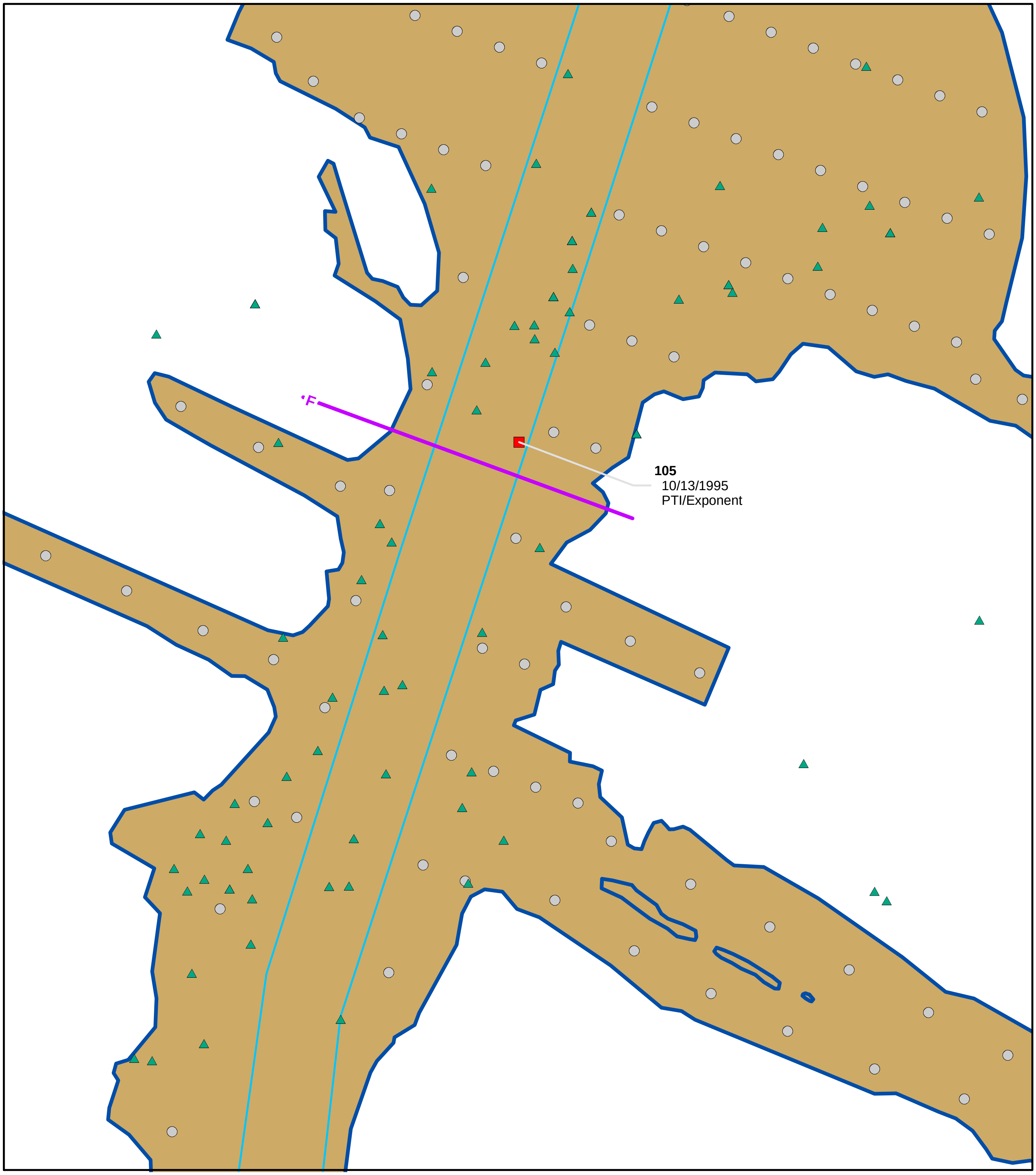
Cross Section C - OU 3 Above De Pere Dam
Figure 2-13 Sheet 3



Cross Section B - OU 3 Mid Reach
Figure 2-13 Sheet 2



Cross Section A - OU 2 Deposit DD Area
Figure 2-13 Sheet 1



Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

N
W E
S

0 500 Feet

Figure 2-12 Sheet 7
Cross-Section F
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

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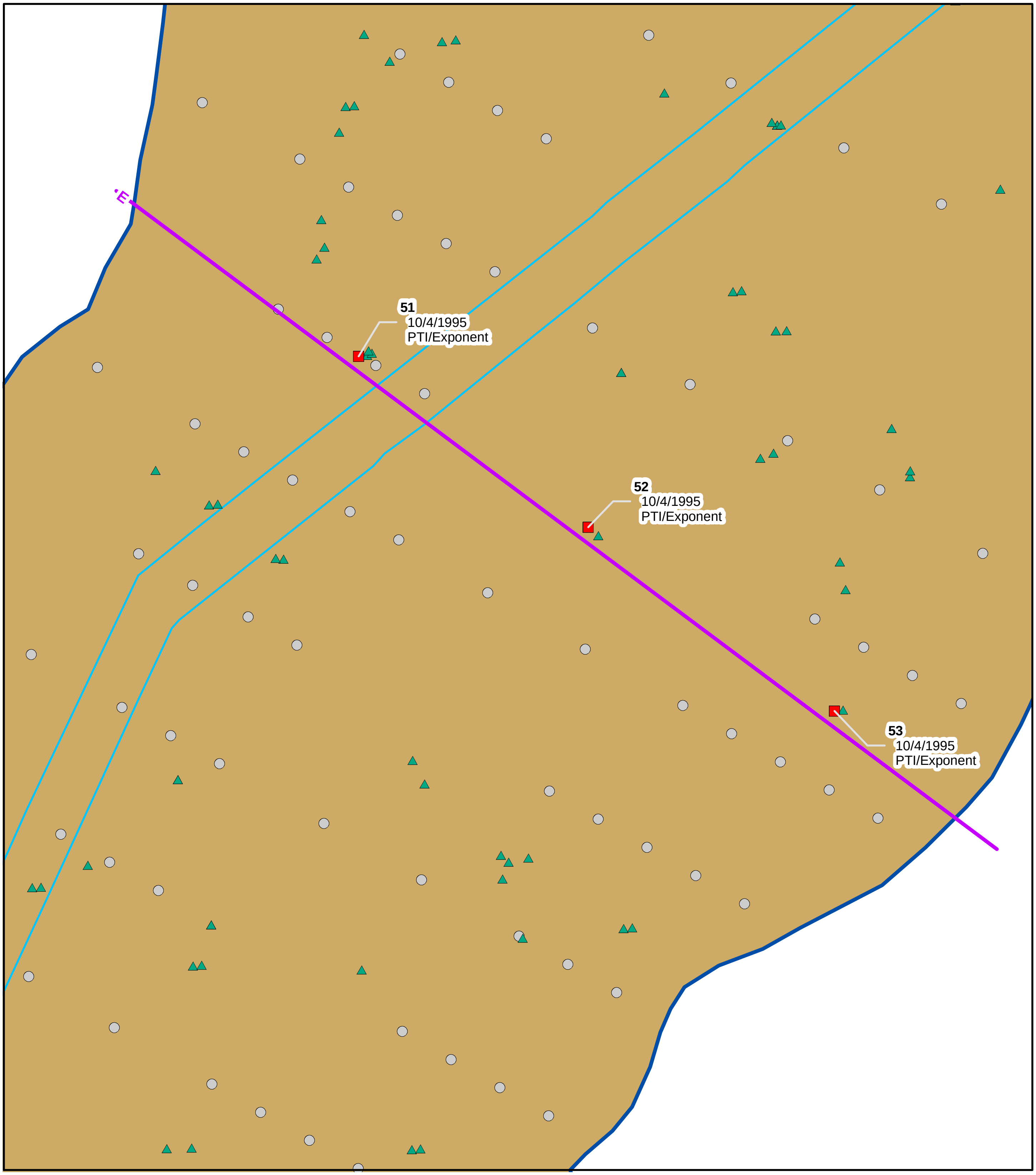


Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

N
W E
S

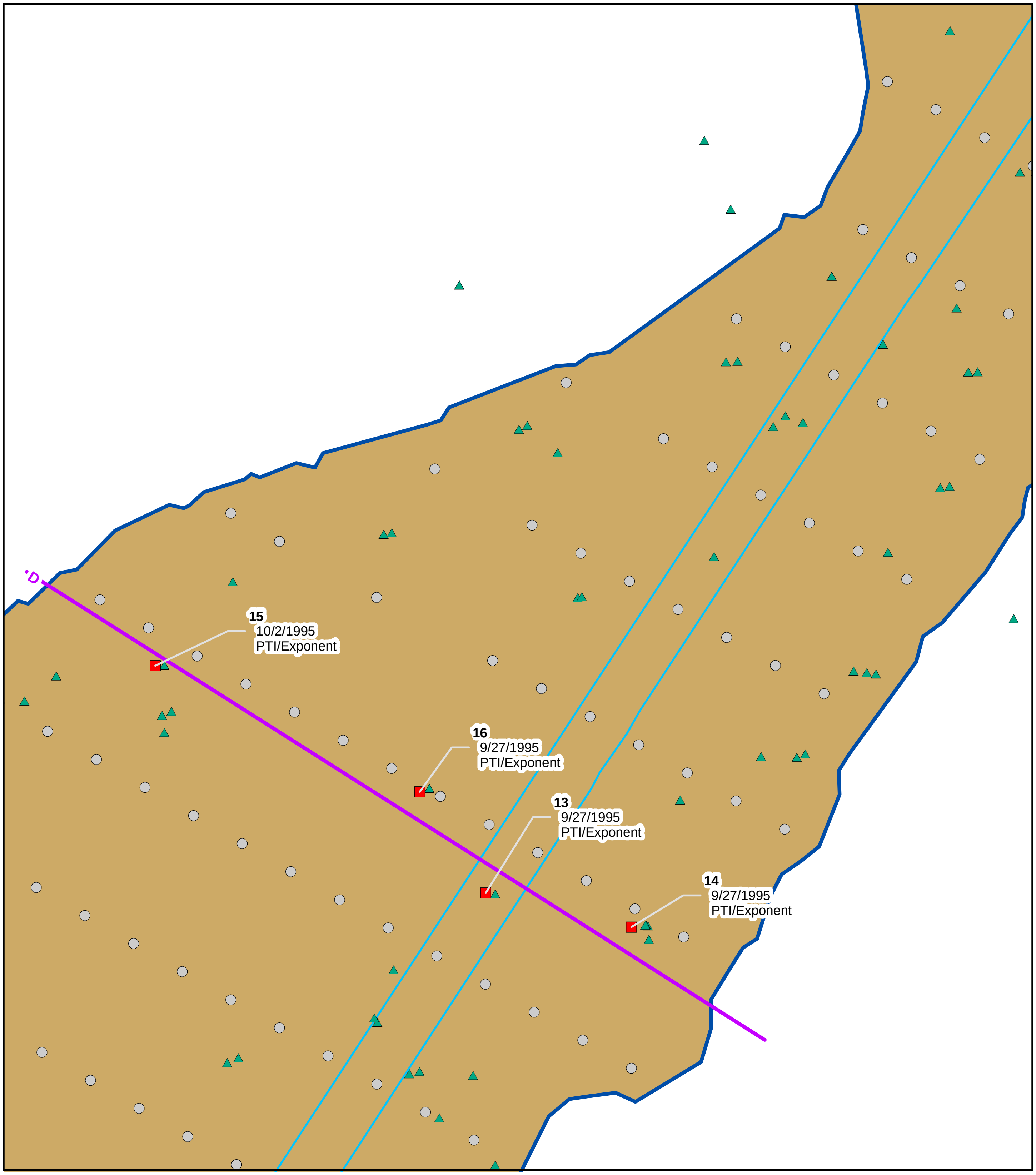
0 400 Feet

Figure 2-12 Sheet 6
Cross-Section E
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

ANCHOR ENVIRONMENTAL, L.L.C.

Shaw®



Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

N
W E
S

0 400 Feet

Figure 2-12 Sheet 5
Cross-Section D
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

ANCHOR ENVIRONMENTAL, L.L.C.

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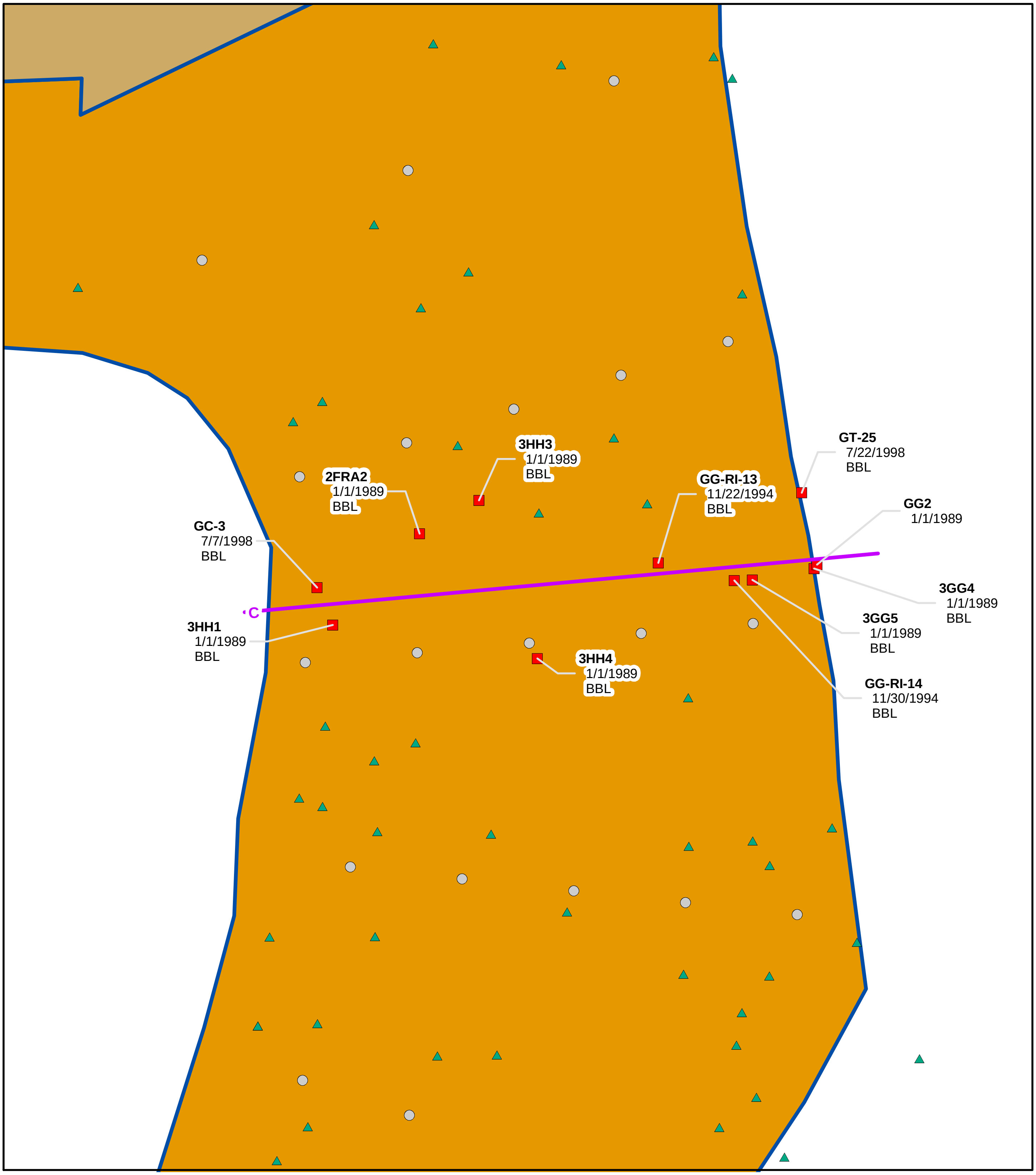

Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

Figure 2-12 Sheet 4
Cross-Section C
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

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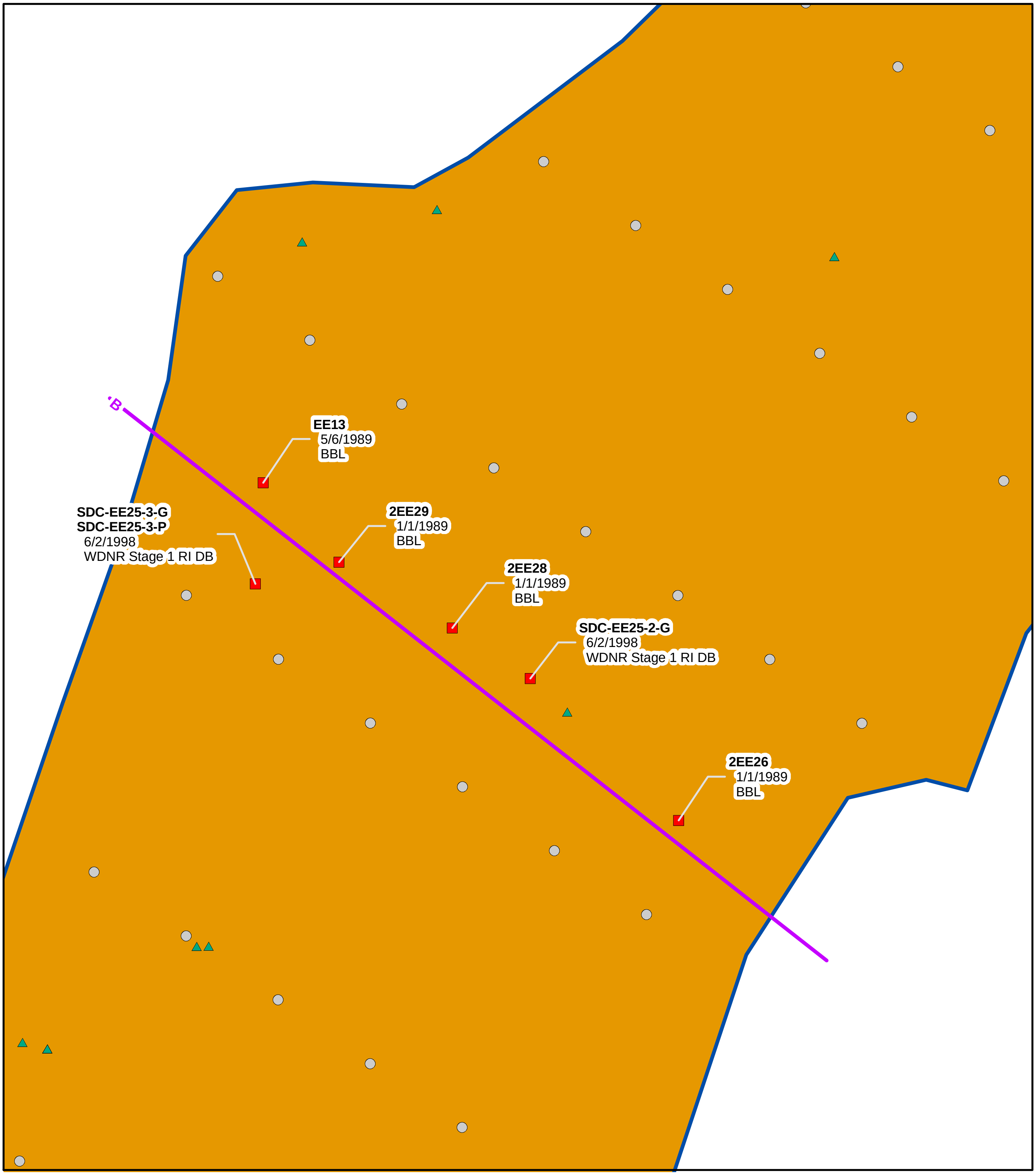

Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

N W E S

0 200 Feet

Figure 2-12 Sheet 3
Cross-Section B
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

ANCHOR ENVIRONMENTAL, L.L.C.

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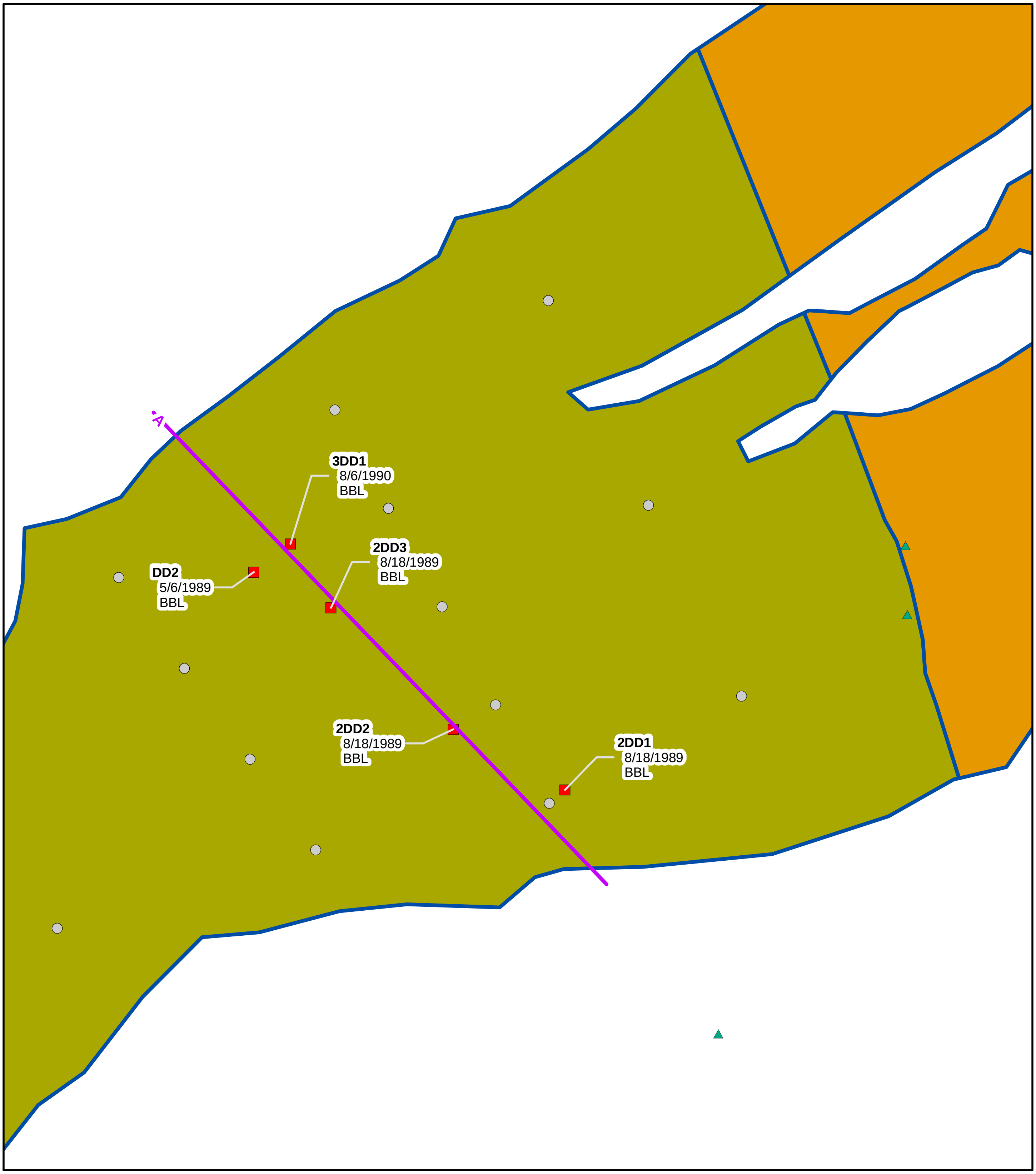

Legend

- Existing Sample Locations
- Cores Used in Cross-sections
- Proposed Core Locations
- Cross-section Lines
- USACE Channel Definition
- Fox River Boundary

Operable Unit

1
2
3
4

N
W E
S

0 200 Feet

Figure 2-12 Sheet 2
Cross-Section A
Plan View

Fox River OU 2 - OU 5 Remedial Design Work Plan

ANCHOR ENVIRONMENTAL, L.L.C.

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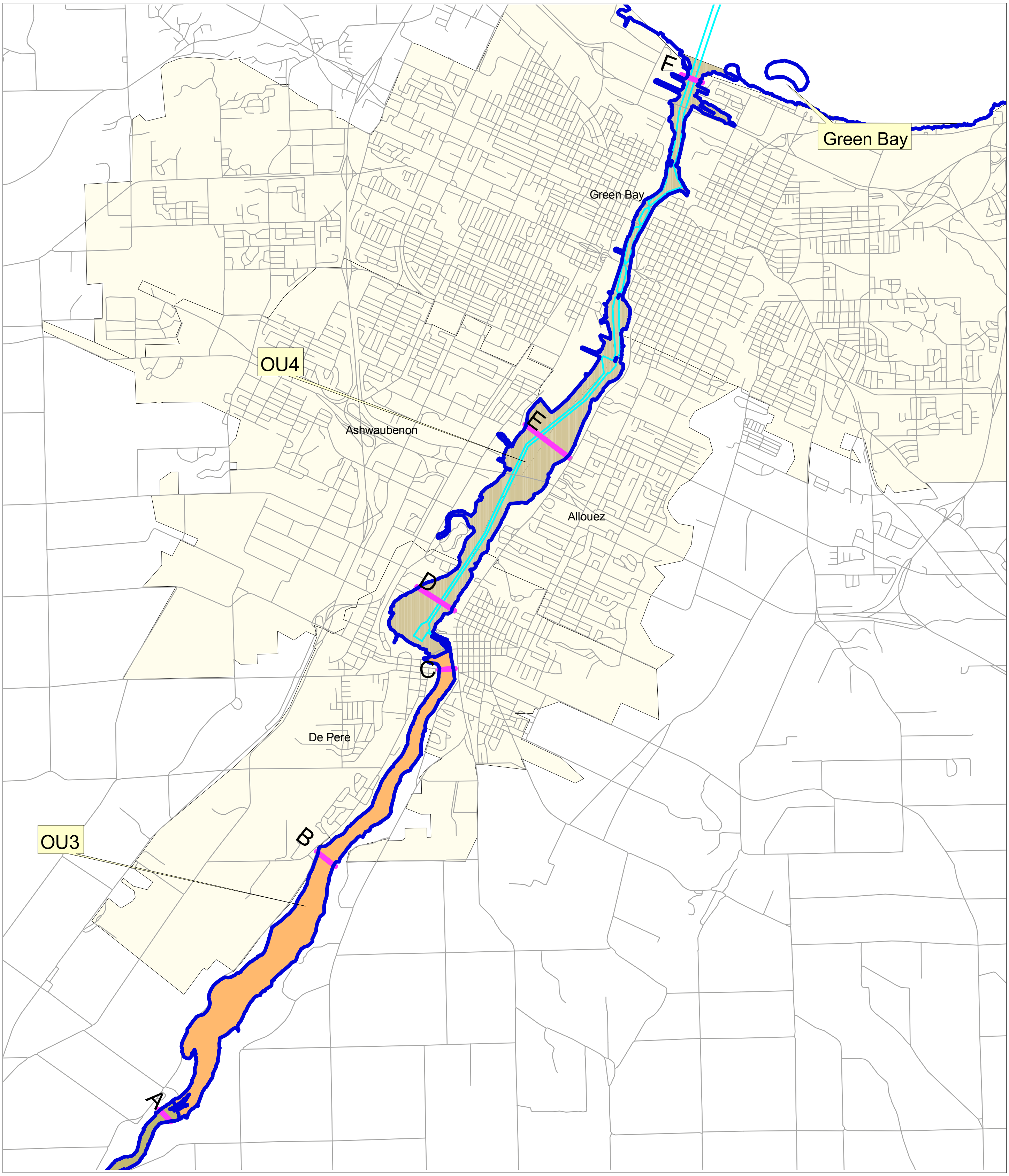

Legend

		Operable Unit	
Roads			1
Cross-section Lines			2
USACE Channel Definition			3
Fox River Boundary			4

N W E S

1 0 1 Miles

Figure 2-12 Sheet 1

Cross-Section Location Map

Fox River OU 2 - OU 5 Remedial Design Work Plan

ANCHOR ENVIRONMENTAL, L.L.C.

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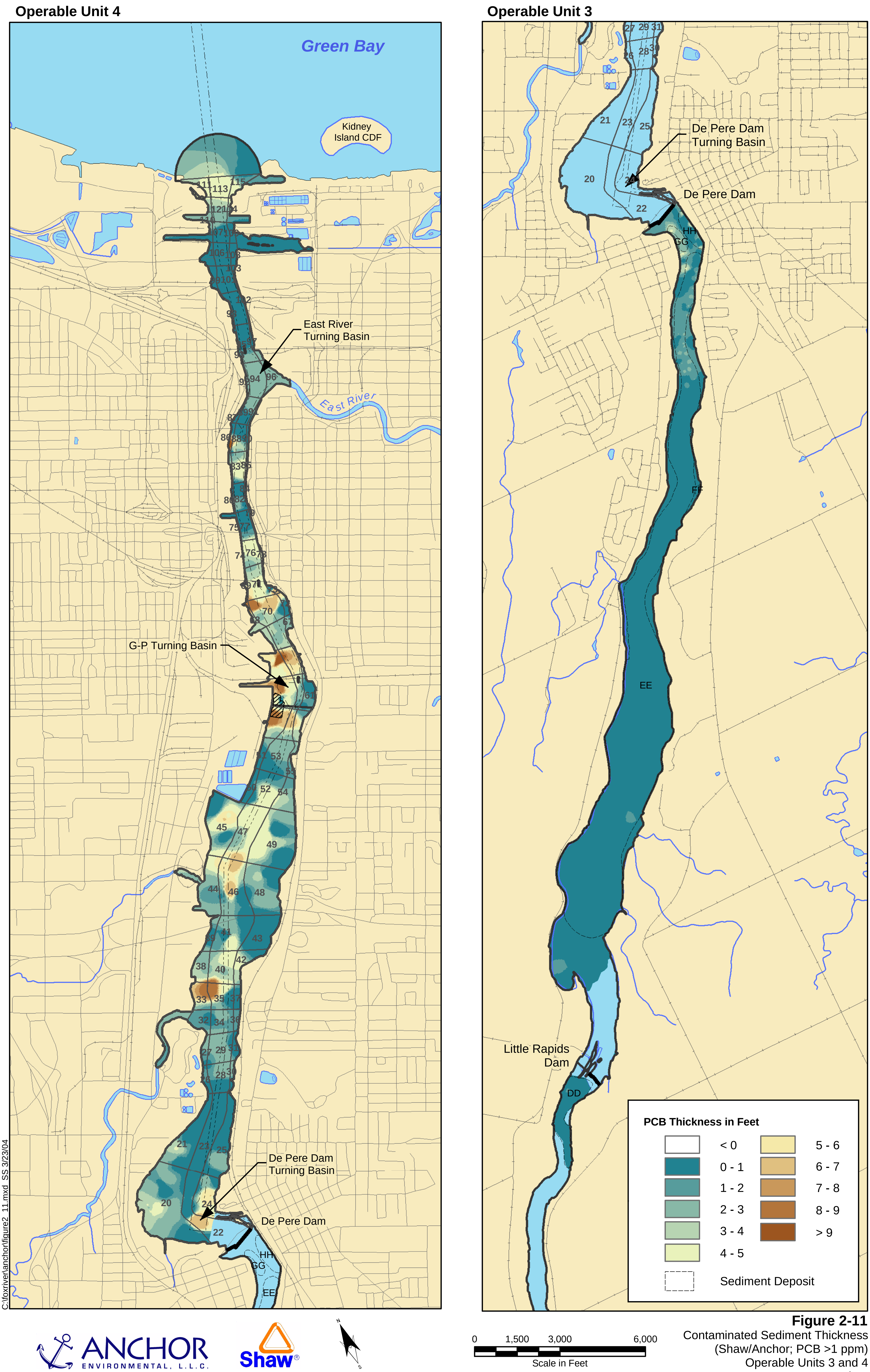

Figure 2-11
Contaminated Sediment Thickness
(Shaw/Anchor; PCB >1 ppm)
Operable Units 3 and 4
Lower Fox River

Operable Unit 4

Operable Unit 3

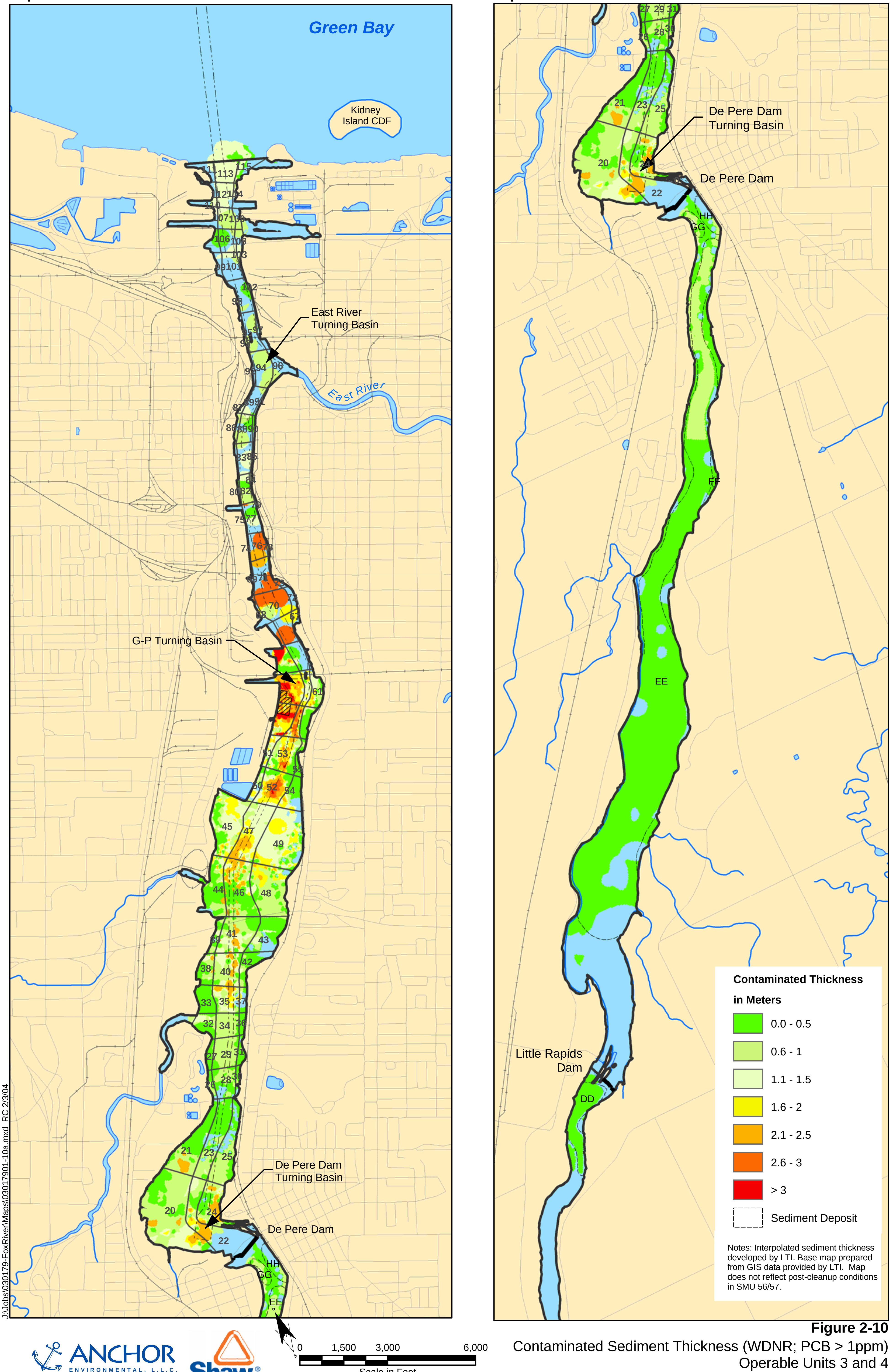

Figure 2-10
Contaminated Sediment Thickness (WDNR; PCB > 1ppm)
Operable Units 3 and 4
Lower Fox River

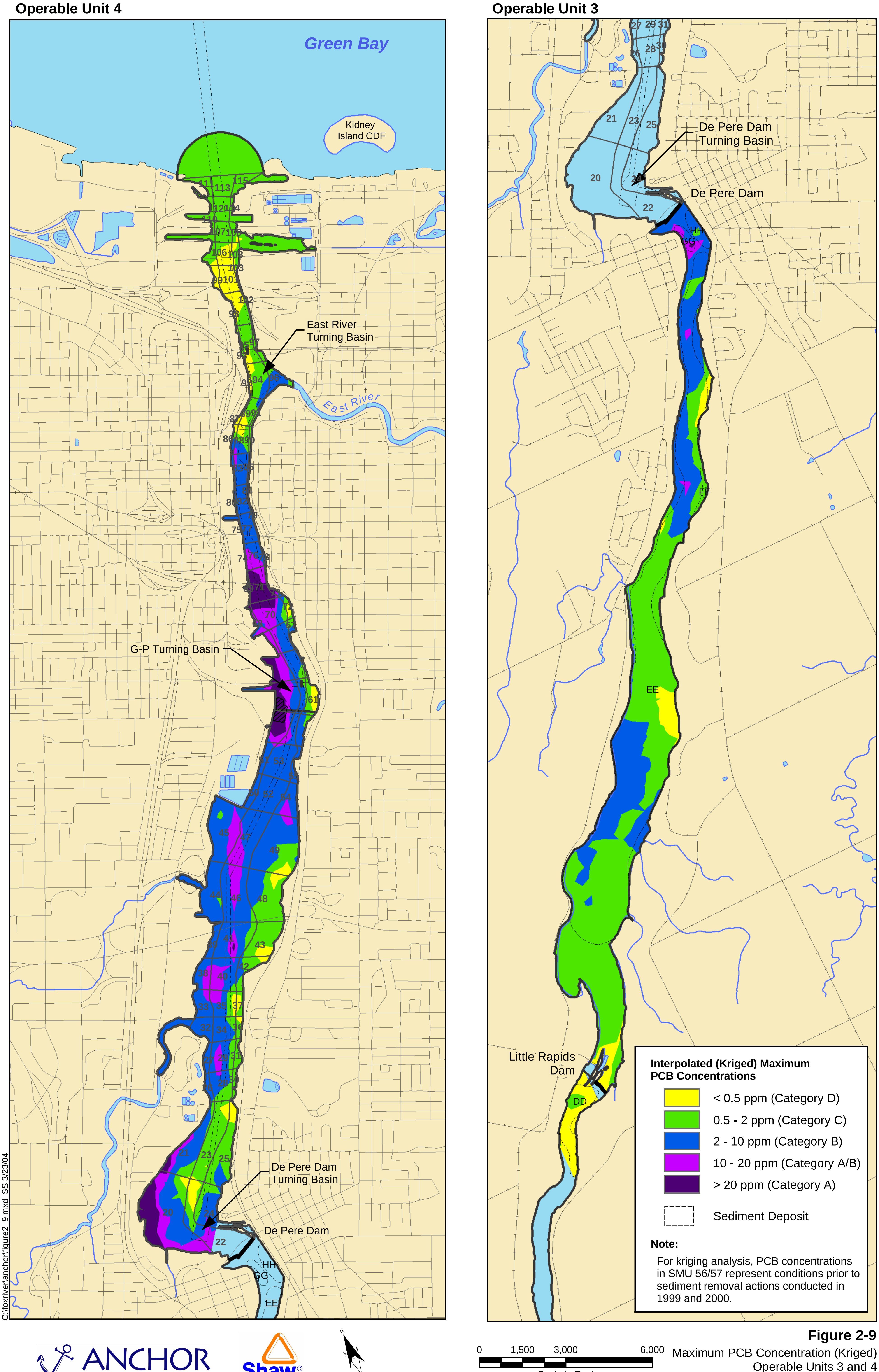

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Figure 2-9
Maximum PCB Concentration (Kriged)
Operable Units 3 and 4
Lower Fox River

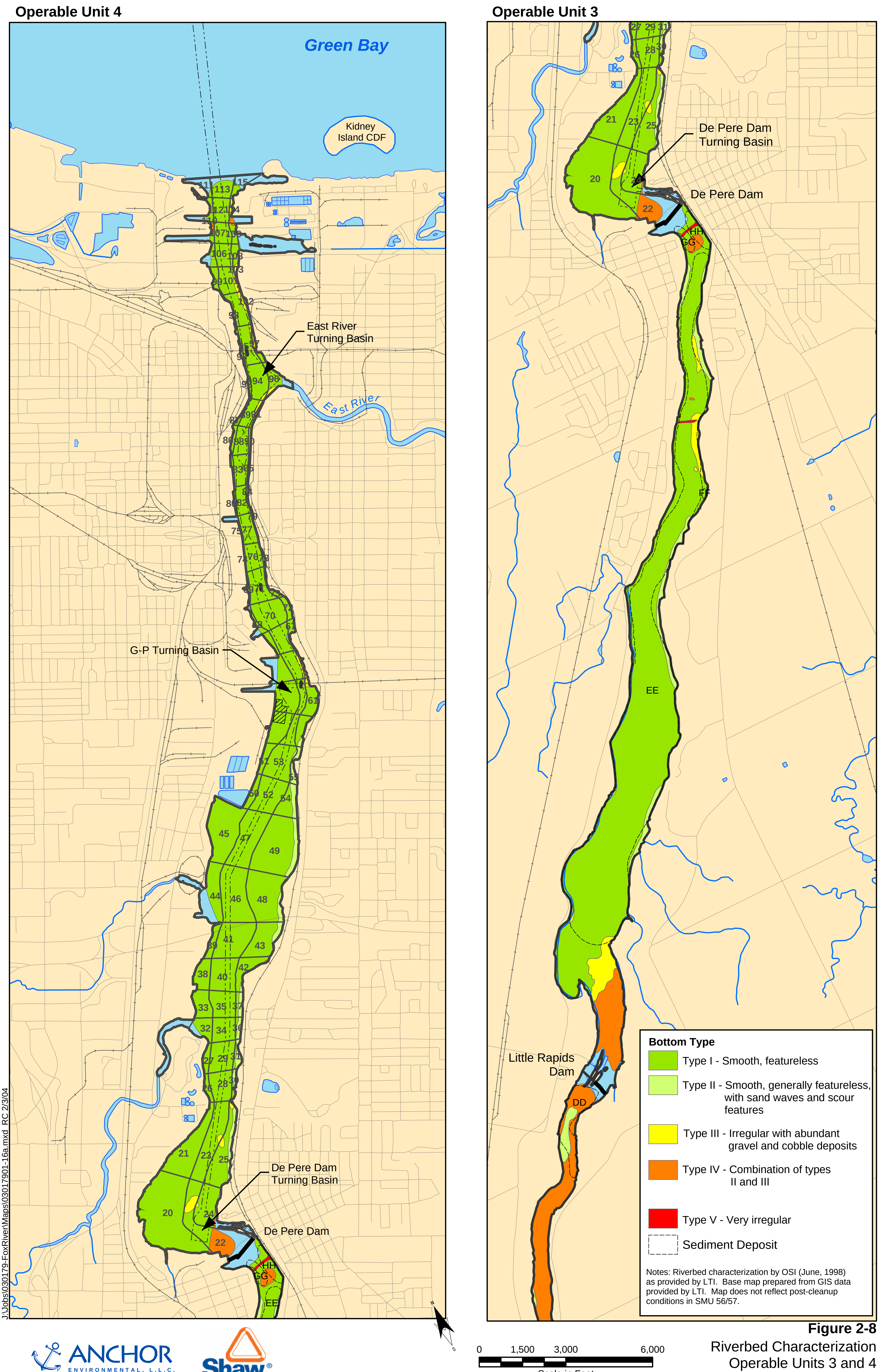

Figure 2-8
Riverbed Characterization
Operable Units 3 and 4
Lower Fox River

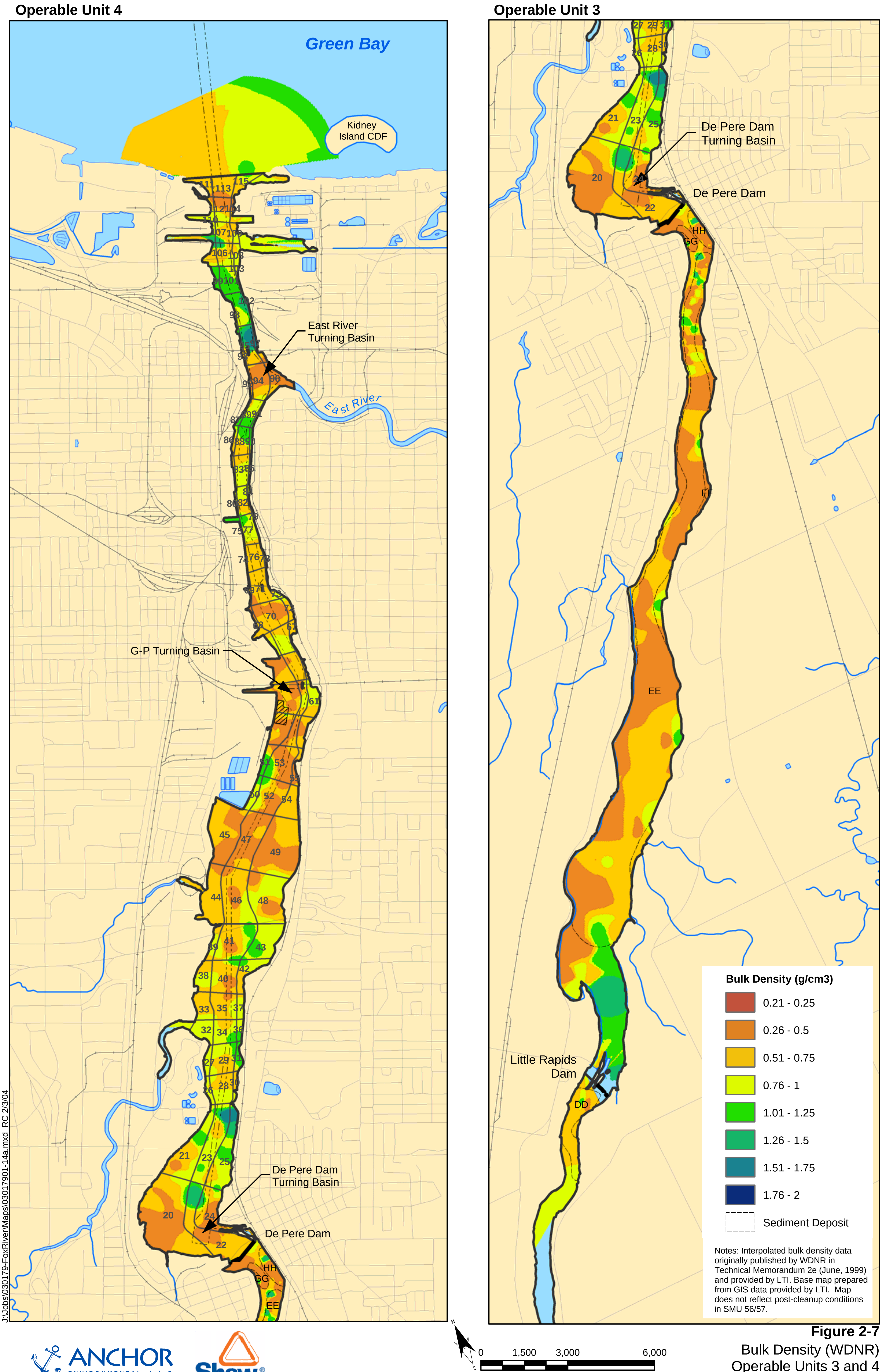

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Figure 2-7
Bulk Density (WDNR)
Operable Units 3 and 4
Lower Fox River

Operable Unit 4 **Operable Unit 3**

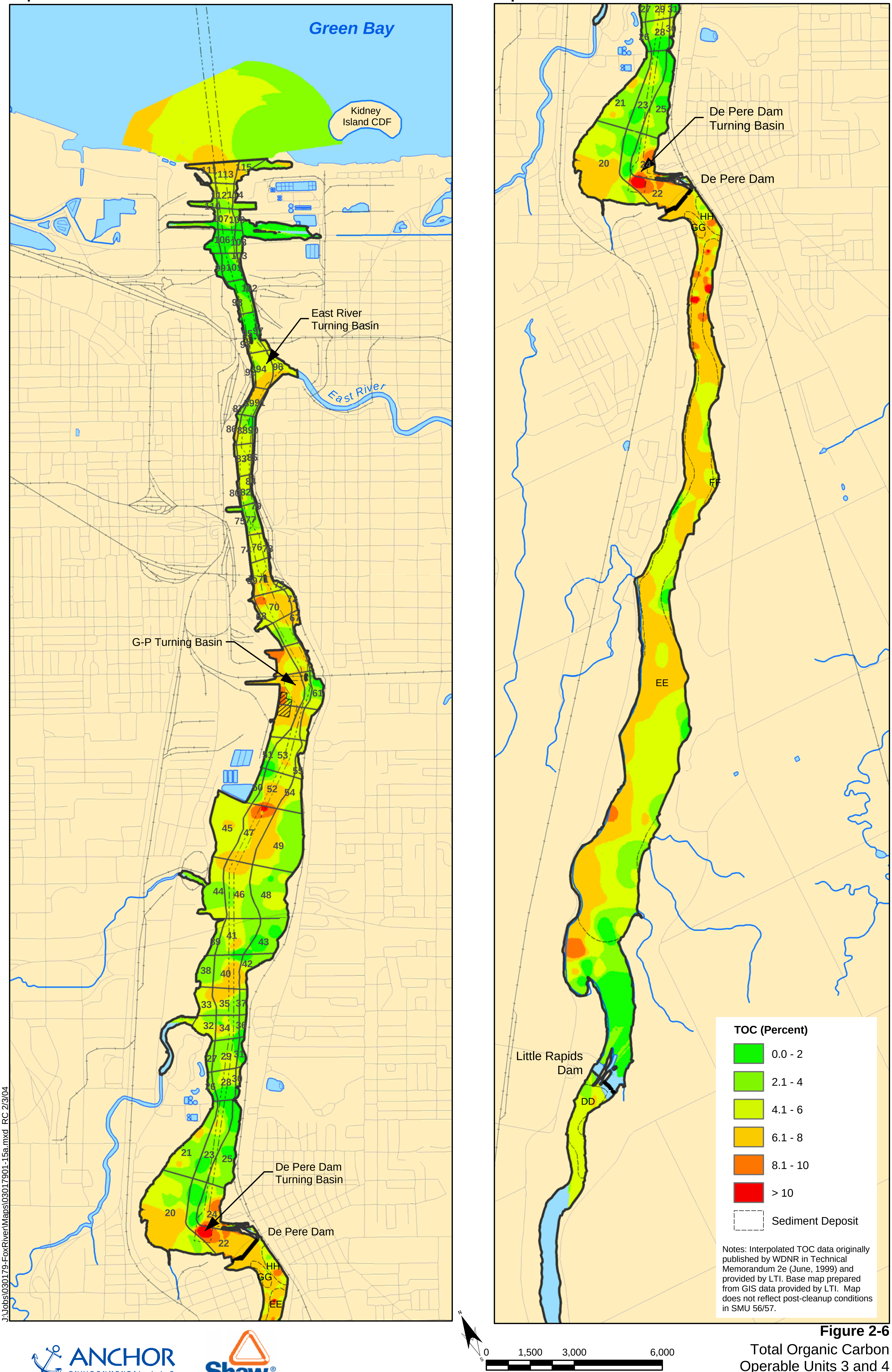

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Figure 2-6
Total Organic Carbon
Operable Units 3 and 4
Lower Fox River

Operable Unit 4

Operable Unit 3

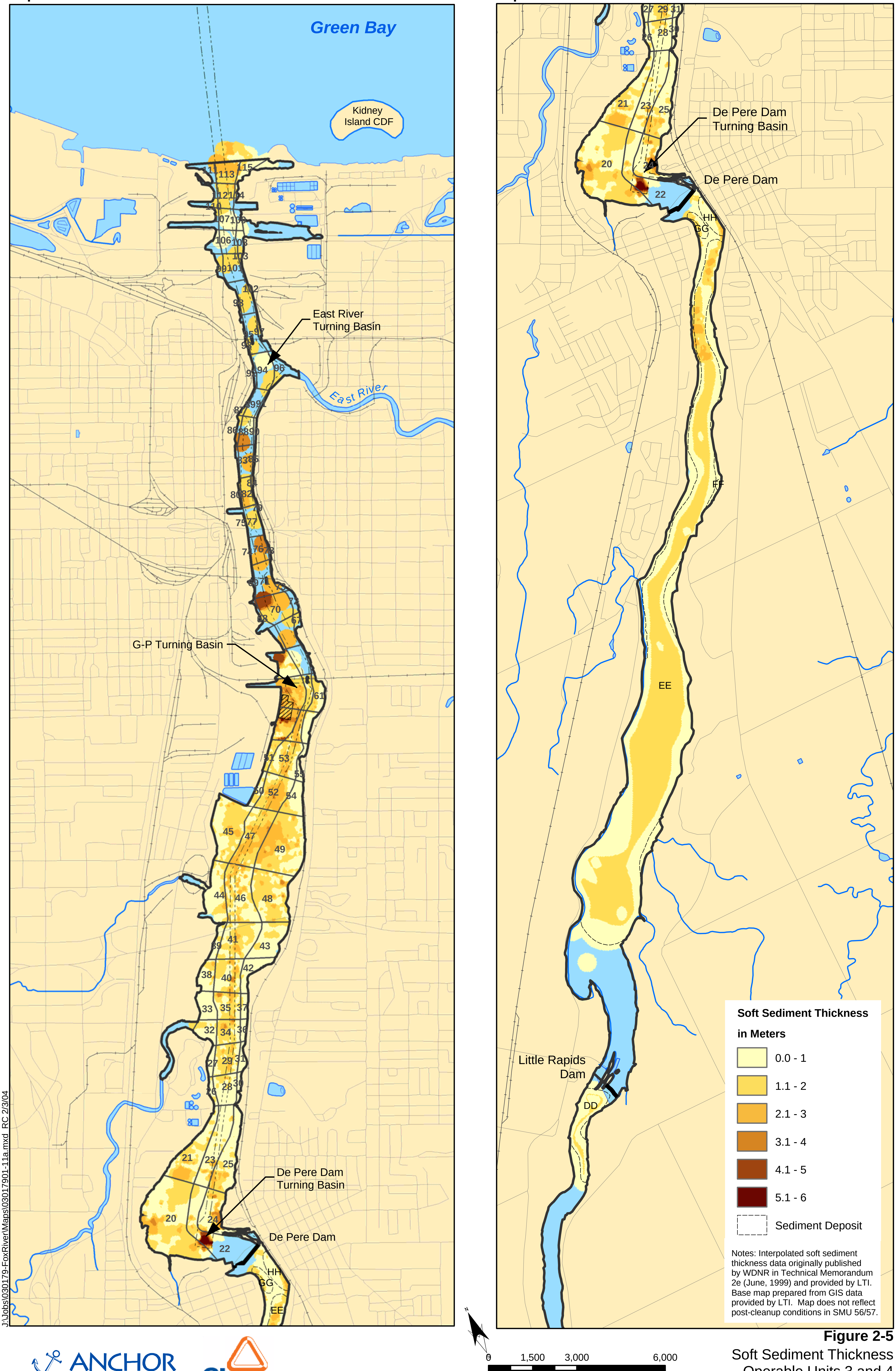

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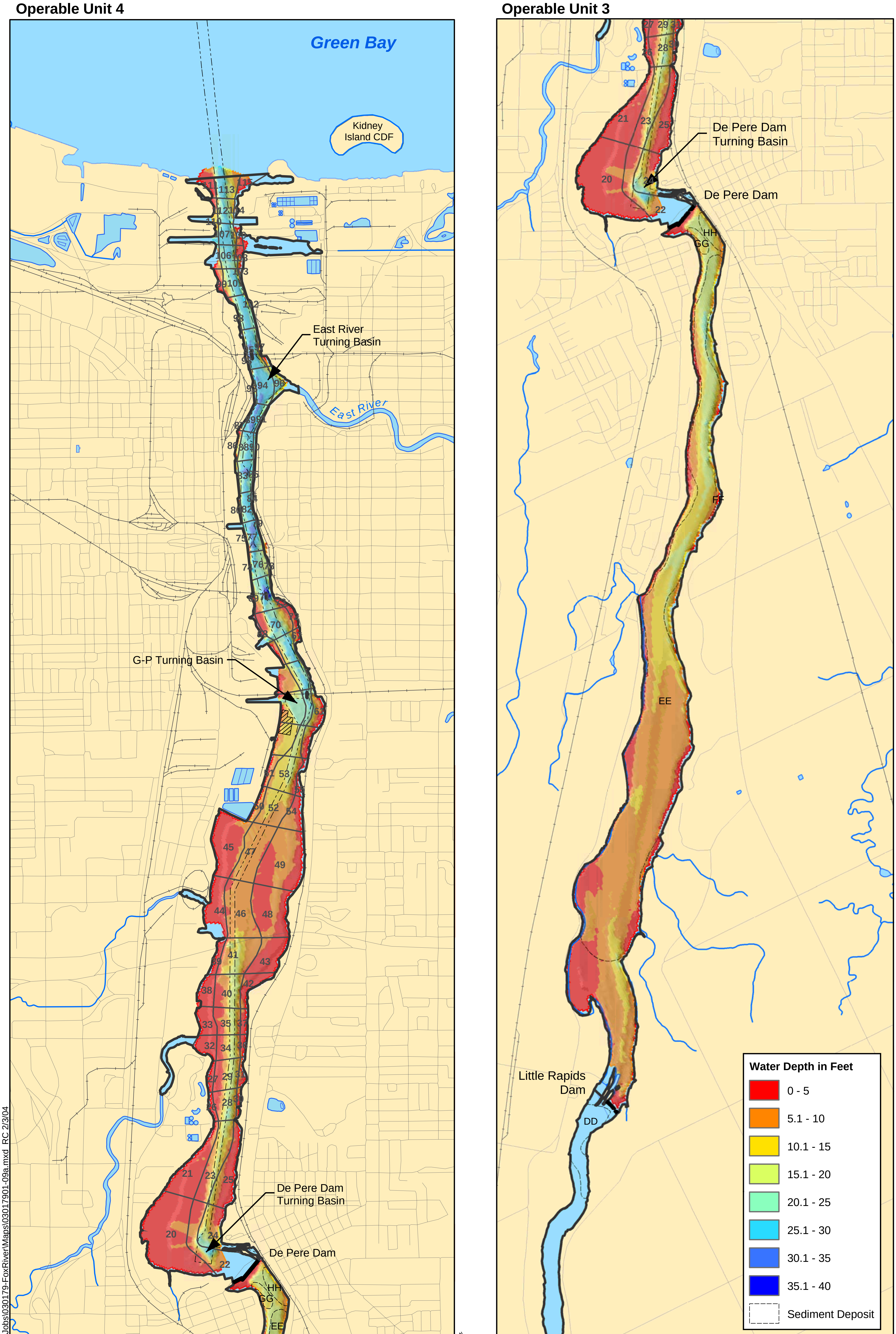
Figure 2-5
Soft Sediment Thickness
Operable Units 3 and 4
Lower Fox River



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Notes: Water depth based on EPA survey data dated Oct-Nov, 2002. Base map prepared from GIS data provided by LTI.

0 1,500 3,000 6,000
Scale in Feet

Figure 2-4
Water Depth Map
Operable Units 3 and 4
Lower Fox River

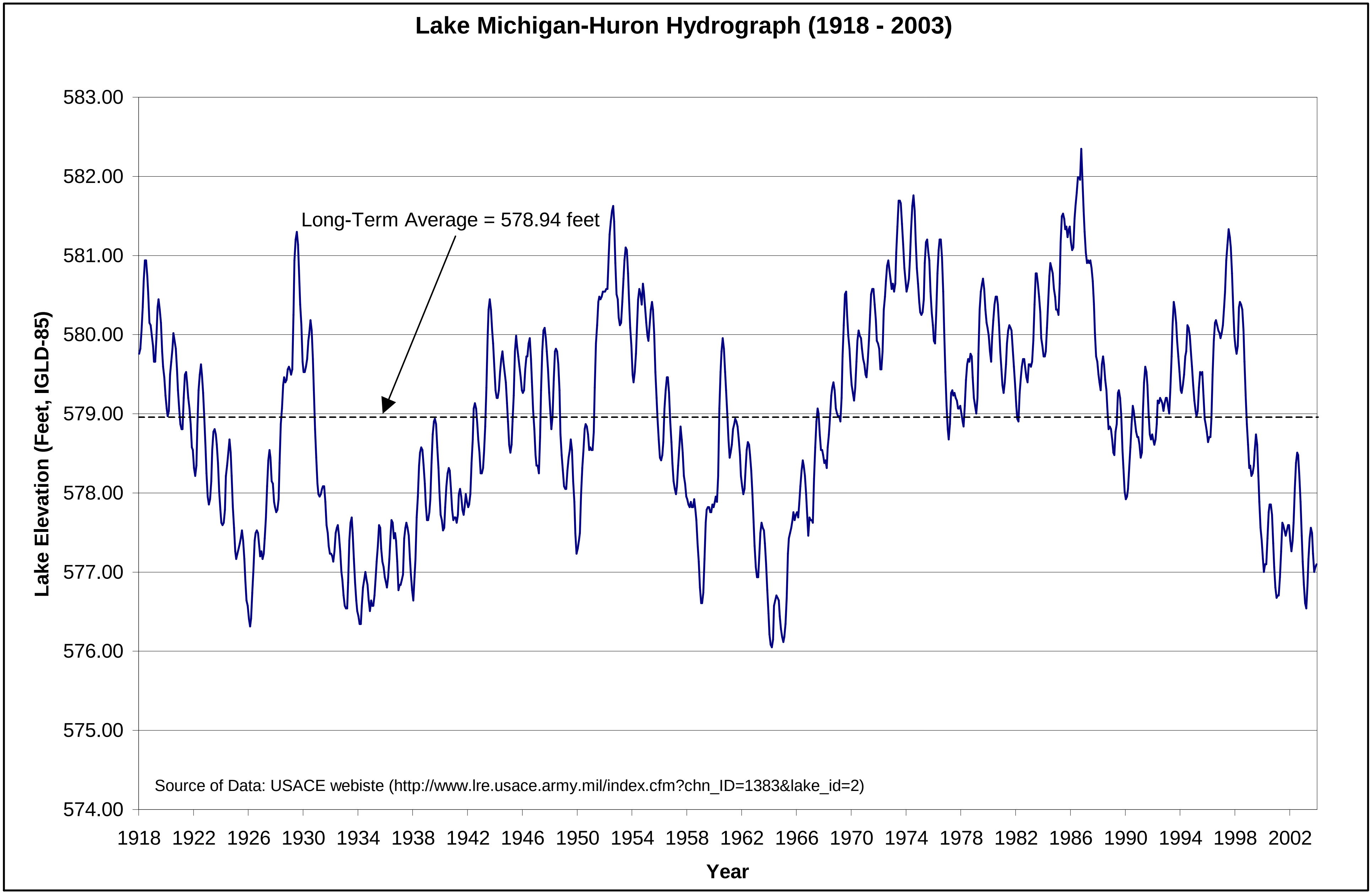

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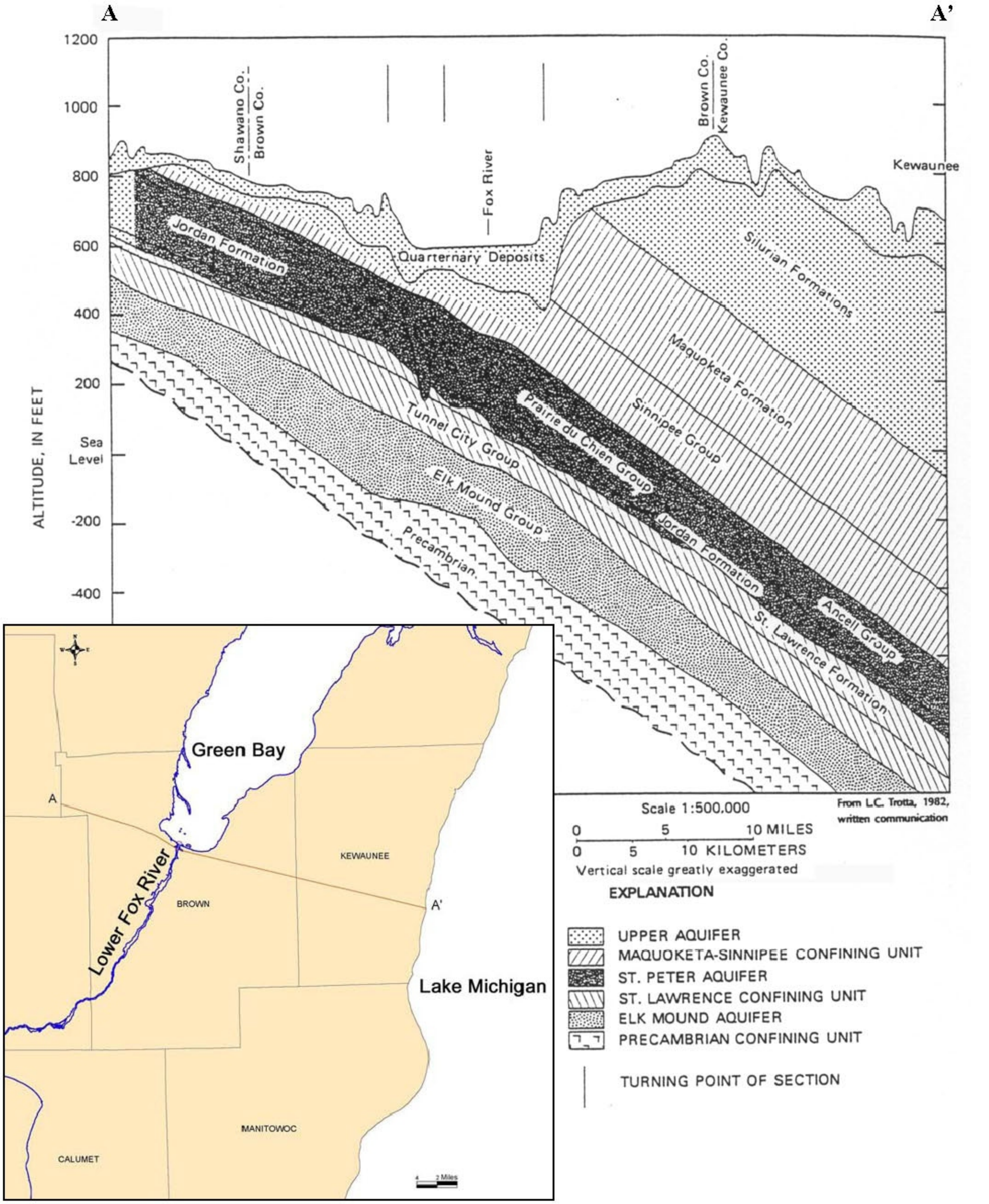
Figure 2-3
Lake Michigan-Huron Hydrograph
(1918 - Present)



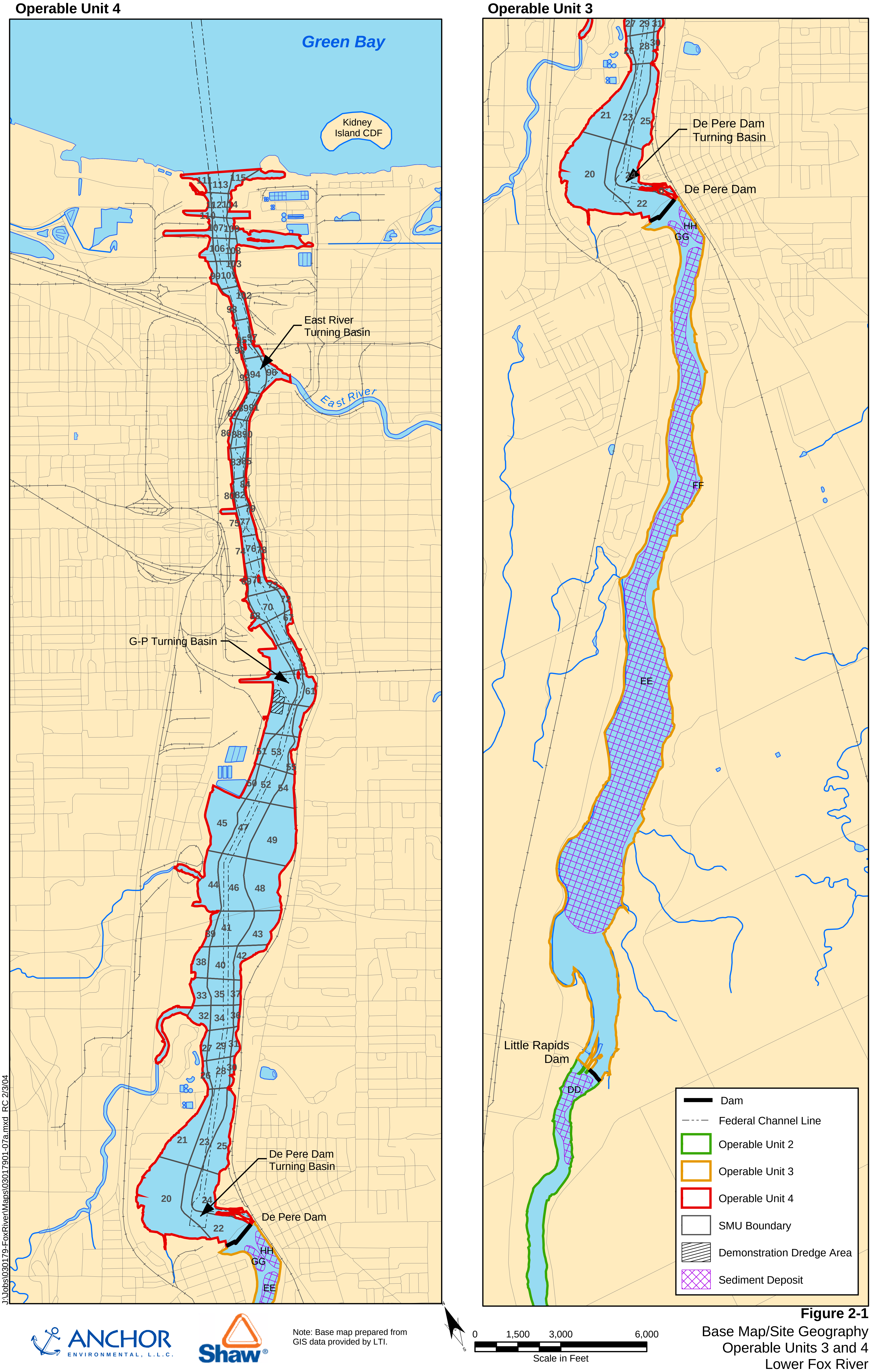
Source: Krohelski and Brown, 1986

ANCHOR ENVIRONMENTAL, L.L.C. Shaw

Figure 2-2
Conceptual Level Cross Section of Lower Fox River Valley Aquifers
Lower Fox River

Operable Unit 4

Operable Unit 3



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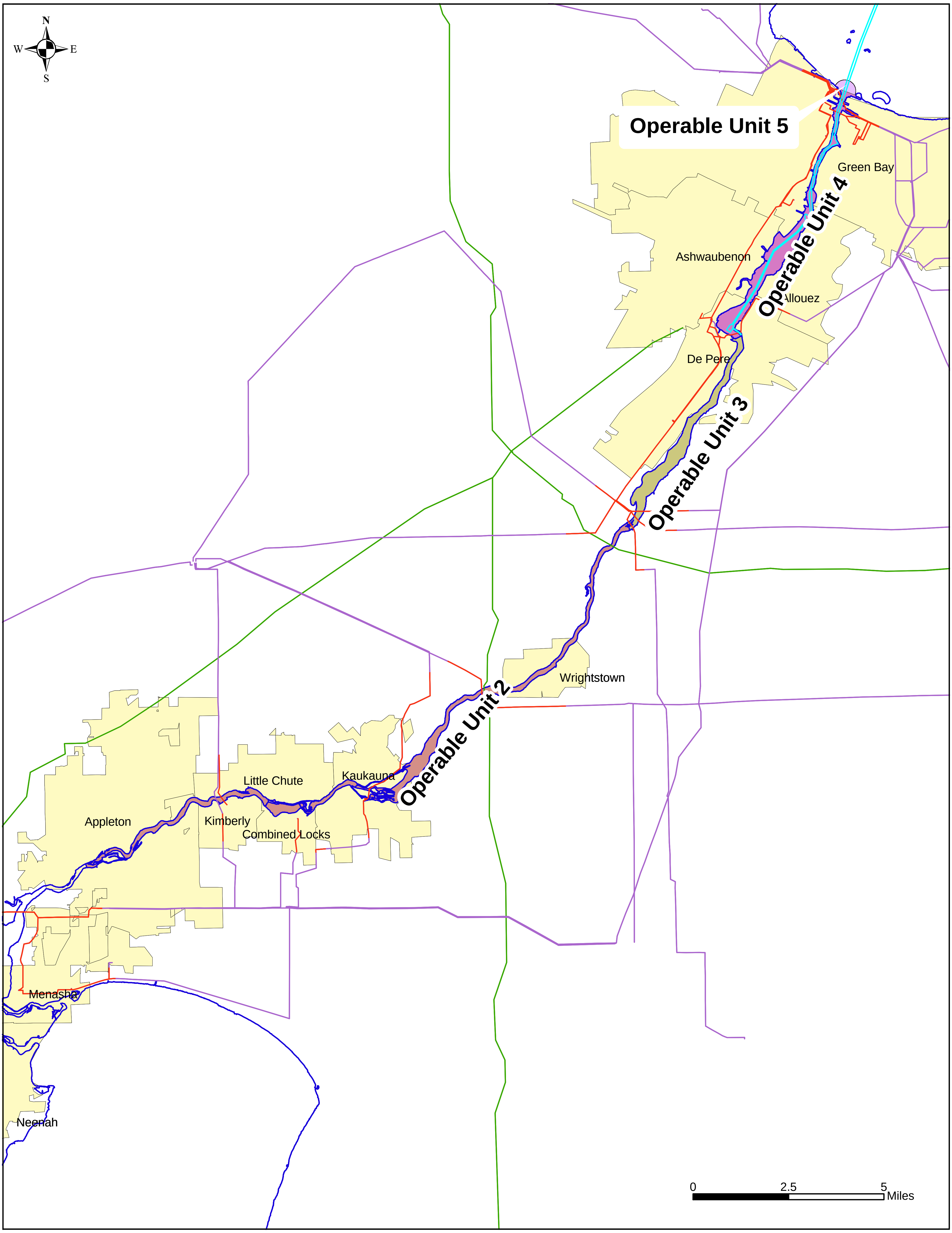
Note: Base map prepared from GIS data provided by LTI.

Figure 2-1
Base Map/Site Geography
Operable Units 3 and 4
Lower Fox River



Legend

Natural Gas Pipeline	
Transmission System	
American Transmission Company Line	
USACE Channel Definition	
Municipal Boundary	
Fox River Boundary	

Operable Unit Number

- 2
- 3
- 4

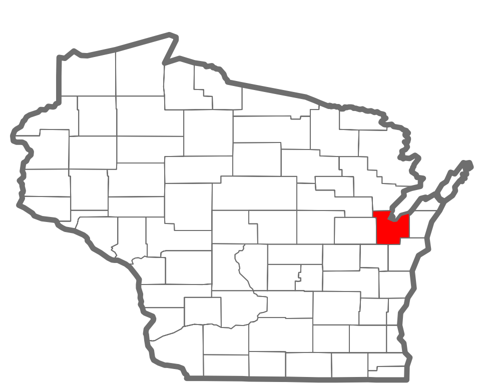


Figure 1-1
Lower Fox River
Area Location Map

Lower Fox River OU 2-OU 5
Remedial Design Work Plan

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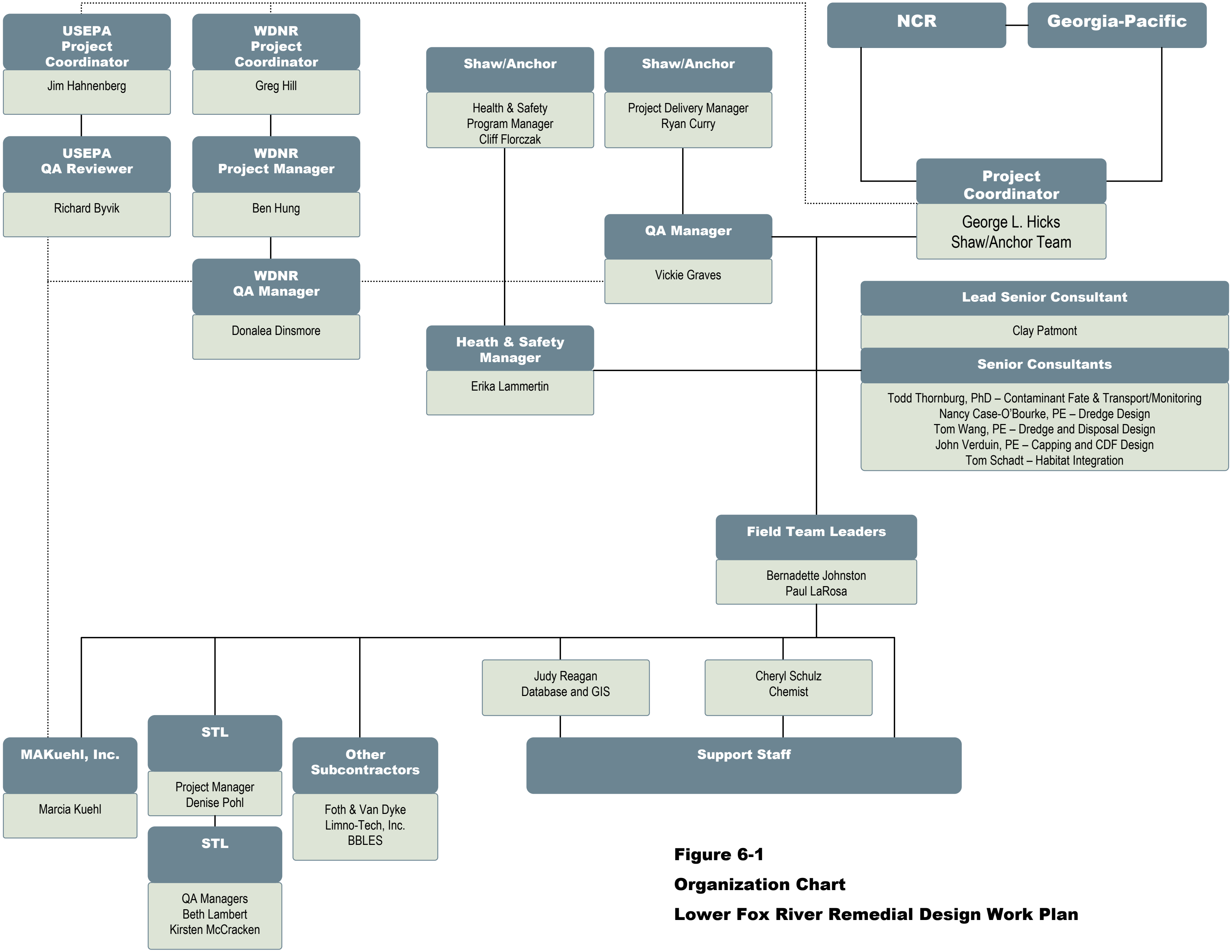

Figure 6-1

Organization Chart

Lower Fox River Remedial Design Work Plan

Table 2-13. Lower Fox River Land Use

Land Use Within 0.25 Miles of the Lower Fox River:

Land Use	% of Total
Residential	29.20%
Industrial/Commercial	25.80%
Woodlans	16.20%
Parks	9.30%
Agriculture	5.80%
Public	4.30%
Wetlands	3.40%
Vacant	6.05
	100.00%

Predominant Land Use Within Each Operable Unit:

Operable Unit	Predominant Land Use
OU 2	Residential, industrial, commercial, and agriculture
OU 3	Agriculture, residential
OU 4	Residential, industrial, commercial, and agriculture
OU 5	Residential, industrial, commercial, and agriculture

Retec, 2002c.

Table 2-12. Average Total PCB Concentration (Estimated) by Depth

Deposit/SMU	Subsurface Depth Interval in centimeters									Avg. PCB (mg/kg)
	0-10	10-30	30-50	50-100	100-150	150-200	200-250	250-300	300-350	
Appleton to Little Rapids										
Deposit I	0.8	0.2	0.0	0.1	-	-	-	-	-	0.2
Deposit J	0.1	0.1	0.0	-	-	-	-	-	-	0.1
Deposit K	0.4	0.1	-	-	-	-	-	-	-	0.2
Deposit L	0.4	0.2	-	-	-	-	-	-	-	0.2
Deposit M	0.6	0.3	0.1	-	-	-	-	-	-	0.3
Deposit N	*7.9*	*14.7*	*13.3*	*6.4*	*-*	*-*	*-*	*-*	*-*	*11.7*
Deposit O	2.1	1.3	-	-	-	-	-	-	-	1.6
Deposit P	0.8	1.2	1.2	0.4	-	-	-	-	-	0.8
Deposit Q	1.6	1.5	-	-	-	-	-	-	-	1.6
Deposit R	0.1	0.1	-	-	-	-	-	-	-	0.1
Deposit S	0.0	0.0	-	-	-	-	-	-	-	0.0
Deposit T	5.2	4.1	0.0	0.0	-	-	-	-	-	2.6
Deposit U	0.9	0.3	-	-	-	-	-	-	-	0.5
Deposit V	1.0	0.0	-	-	-	-	-	-	-	0.6
Deposit W	0.3	0.1	0.0	0.1	-	-	-	-	-	0.1
Deposit X	0.1	0.0	0.1	0.1	-	-	-	-	-	0.1
Deposit Y	0.5	0.1	0.0	-	-	-	-	-	-	0.2
Deposit Z	0.4	0.1	0.1	0.1	-	-	-	-	-	0.1
Deposit AA	0.1	0.1	-	-	-	-	-	-	-	0.1
Deposit BB	0.2	0.1	-	-	-	-	-	-	-	0.1
Deposit CC	0.3	0.1	0.1	-	-	-	-	-	-	0.2
Deposit DD	1.0	1.8	4.9	0.3	-	-	-	-	-	2.0
Reach Total	0.8	0.8	0.9	0.2	-	-	-	-	-	0.7
Little Rapids to De Pere										
Deposit EE	1.9	1.0	0.9	0.4	0.1	0.0	0.0	-	-	0.8
Deposit FF	0.2	0.0	0.1	-	-	-	-	-	-	0.1
Deposit GG	7.5	12.2	14.1	7.0	3.8	0.2	-	-	-	8.5
Deposit HH	5.4	7.1	7.3	4.6	1.2	0.1	0.0	-	-	4.5
Reach Total	2.0	1.2	1.0	0.5	0.4	0.0	0.0	-	-	0.9
De Pere to Green Bay										
SMUs 20-25	4.4	8.9	11.8	10.4	9.4	8.7	25.3	-	-	10.1
SMUs 26-31	5.5	15.1	13.0	9.6	0.3	0.2	0.2	-	-	8.8
SMUs 32-37	4.2	13.7	11.7	11.6	8.7	2.0	3.6	3.3	-	9.7
SMUs 38-43	2.4	7.0	9.1	6.7	1.7	0.5	1.5	9.2	28.8	5.5
SMUs 44-49	3.5	6.7	9.1	10.2	6.9	3.5	2.2	8.8	5.1	7.3
SMUs 50-55	3.0	4.2	10.5	9.9	7.9	10.0	15.5	24.4	17.9	8.7
SMUs 56-61	*2.2*	*7.6*	*21.5*	*34.6*	*28.0*	*22.3*	*22.2*	*10.8*	*10.5*	*21.8*
SMUs 62-67	1.9	2.7	3.9	5.9	12.6	11.9	16.0	4.7	7.3	8.7
SMUs 68-73	3.4	7.8	12.0	12.2	13.2	6.7	9.3	16.2	-	10.6
SMUs 74-79	5.8	12.2	4.9	4.2	1.7	1.7	4.3	22.8	-	5.8
SMUs 80-85	5.1	3.6	8.4	8.8	3.7	0.3	0.2	-	-	4.5
SMUs 86-91	1.5	2.2	2.7	8.3	10.0	0.3	0.2	-	-	4.7
SMUs 92-97	1.4	3.3	3.3	4.6	10.0	0.2	-	-	-	4.2
SMUs 98-103	1.0	0.5	0.6	0.6	21.8	-	-	-	-	2.2
SMUs 104-109	1.8	0.8	2.0	2.3	18.6	-	-	-	-	3.9
SMUs 110-115	2.5	1.9	1.1	6.6	13.2	12.9	-	-	-	7.8
Reach Total	3.4	7.3	9.9	10.9	10.0	7.8	11.6	14.0	10.3	9.1

Notes:
- (dotted) Area of sediment remediation demonstration project.
- (yellow) 0 to 10 mg/kg estimated average Total PCBs.
- (orange) 10 to 20 mg/kg estimated average Total PCBs.
- (pink) > 20 mg/kg estimated average Total PCBs.
- (green) Suspect value due to uncertainty in deep-interval interpolation.

WDNR, 1999b and Retec, 2002c.

Table 2-11. Estimated Contaminated Sediment Volume (m^3) by Depth Interval

Deposit/SMU	Subsurface Depth Interval in centimeters									Total
	0-10	10-30	30-50	50-100	100-150	150-200	200-250	250-300	300-350	Mass (kg)
Appleton to Little Rapids										
Deposit I	680	1,360	780	750	-	-	-	-	-	3,570
Deposit J	530	1,060	40	-	-	-	-	-	-	1,630
Deposit K	160	320	-	-	-	-	-	-	-	480
Deposit L	190	380	-	-	-	-	-	-	-	570
Deposit M	470	940	240	-	-	-	-	-	-	1,650
Deposit N	1,680	1,940	1,060	200	-	-	-	-	-	4,880
Deposit O	810	1,620	-	-	-	-	-	-	-	2,430
Deposit P	2,440	2,740	2,520	5,100	-	-	-	-	-	12,800
Deposit Q	70	140	-	-	-	-	-	-	-	210
Deposit R	330	660	-	-	-	-	-	-	-	990
Deposit S	3,090	6,180	3,280	-	-	-	-	-	-	12,550
Deposit T	1,620	3,220	2,020	1,500	-	-	-	-	-	8,360
Deposit U	200	400	-	-	-	-	-	-	-	600
Deposit V	20	40	-	-	-	-	-	-	-	60
Deposit W	15,060	29,860	17,740	17,000	-	-	-	-	-	79,660
Deposit X	11,230	21,740	13,280	11,150	-	-	-	-	-	57,400
Deposit Y	430	860	40	-	-	-	-	-	-	1,330
Deposit Z	730	1,460	940	1,150	-	-	-	-	-	4,280
Deposit AA	130	260	-	-	-	-	-	-	-	390
Deposit BB	260	520	-	-	-	-	-	-	-	780
Deposit CC	4,020	8,020	2,260	-	-	-	-	-	-	14,300
Deposit DD	7,480	14,820	5,820	3,900	-	-	-	-	-	32,020
Reach Total	51,630	98,540	50,020	40,750	-	-	-	-	-	240,940
Little Rapids to De Pere										
Deposit EE	229,110	456,700	414,580	844,950	54,150	33,150	6,800	-	-	2,039,440
Deposit FF	360	700	340	-	-	-	-	-	-	1,400
Deposit GG	2,180	3,720	3,120	5,500	3,050	750	-	-	-	18,320
Deposit HH	3,560	5,300	4,740	8,100	5,300	2,550	650	-	-	30,200
Reach Total	235,210	466,420	422,780	858,550	62,500	36,450	7,450	-	-	2,089,360
De Pere to Green Bay										
SMUs 20-25	98,050	175,280	154,500	291,200	192,150	94,850	48,550	-	-	1,054,580
SMUs 26-31	20,100	34,460	26,820	49,550	24,600	8,700	2,000	-	-	166,230
SMUs 32-37	26,080	45,620	32,880	63,650	39,050	16,250	7,300	2,400	-	233,230
SMUs 38-43	43,280	72,400	63,280	124,350	63,850	23,400	8,300	2,400	1,100	402,360
SMUs 44-49	104,730	198,500	181,860	389,300	284,350	150,100	62,350	7,300	1,200	1,379,690
SMUs 50-55	30,930	54,940	51,360	113,050	83,900	49,100	17,750	4,000	250	405,280
SMUs 56-61	27,910	52,340	49,540	114,650	98,750	75,450	42,800	18,400	8,800	457,640
SMUs 62-67	11,700	17,720	16,900	39,650	35,650	33,700	22,850	6,600	5,800	190,570
SMUs 68-73	13,390	26,780	26,780	66,950	66,950	66,950	41,150	28,300	-	337,250
SMUs 74-79	7,350	14,700	14,700	36,750	22,850	22,600	12,200	10,800	-	141,950
SMUs 80-85	8,050	16,100	16,100	40,250	38,200	23,700	22,250	-	-	164,650
SMUs 86-91	6,170	12,340	12,340	22,750	21,950	18,600	9,250	-	-	103,400
SMUs 92-97	9,960	19,920	19,920	49,800	11,550	7,350	-	-	-	118,500
SMUs 98-103	7,590	15,180	15,180	37,950	6,300	-	-	-	-	82,200
SMUs 104-109	9,860	19,720	13,820	21,450	9,700	-	-	-	-	74,550
SMUs 110-115	13,000	24,680	24,020	58,650	55,900	30,000	-	-	-	206,250
Reach Total	438,150	800,680	720,000	1,519,950	1,055,700	620,750	296,750	80,200	17,150	5,518,330

Notes: [shaded box] Area of sediment remediation demonstration project.
WDNR, 1999b and Retec, 2002c.

Table 2-10. Estimated PCB (kg) by Depth Interval

Deposit/SMU	Subsurface Depth Interval in centimeters									Total Mass (kg)
	0-10	10-30	30-50	50-100	100-150	150-200	200-250	250-300	300-350	
Appleton to Little Rapids										
Deposit I	0	0	0	0	-	-	-	-	-	0
Deposit J	0	0	0	-	-	-	-	-	-	0
Deposit K	0	0	-	-	-	-	-	-	-	0
Deposit L	0	0	-	-	-	-	-	-	-	0
Deposit M	0	0	0	-	-	-	-	-	-	0
Deposit N	*7*	*15*	*7*	*1*	-	-	-	-	-	*30*
Deposit O	1	1	-	-	-	-	-	-	-	2
Deposit P	1	2	2	1	-	-	-	-	-	5
Deposit Q	0	0	-	-	-	-	-	-	-	0
Deposit R	0	0	-	-	-	-	-	-	-	0
Deposit S	0	0	-	-	-	-	-	-	-	0
Deposit T	4	7	0	0	-	-	-	-	-	11
Deposit U	0	0	-	-	-	-	-	-	-	0
Deposit V	0	0	-	-	-	-	-	-	-	0
Deposit W	3	2	0	1	-	-	-	-	-	6
Deposit X	1	0	0	1	-	-	-	-	-	2
Deposit Y	0	0	0	-	-	-	-	-	-	0
Deposit Z	0	0	0	0	-	-	-	-	-	0
Deposit AA	0	0	-	-	-	-	-	-	-	0
Deposit BB	0	0	-	-	-	-	-	-	-	0
Deposit CC	1	0	0	-	-	-	-	-	-	1
Deposit DD	4	14	15	1	-	-	-	-	-	33
Reach Total	22	42	25	4	-	-	-	-	-	93
Little Rapids to De Pere										
Deposit EE	225	247	184	183	4	1	0	-	-	844
Deposit FF	0	0	0	-	-	-	-	-	-	0
Deposit GG	8	24	23	20	6	0	-	-	-	81
Deposit HH	10	20	18	19	3	0	0	-	-	70
Reach Total	244	291	225	222	13	1	0	-	-	996
De Pere to Green Bay										
SMUs 20-25	226	814	950	1,569	936	430	638	-	-	5,562
SMUs 26-31	57	271	181	247	4	1	0	-	-	762
SMUs 32-37	57	324	199	383	177	17	14	4	-	1,175
SMUs 38-43	53	265	300	436	57	6	6	11	16	1,152
SMUs 44-49	189	697	856	2,069	1,021	275	72	33	3	5,215
SMUs 50-55	49	121	281	584	345	256	143	51	2	1,832
SMUs 56-61	32	207	553	2,061	1,439	874	495	103	48	5,176
SMUs 62-67	12	25	34	121	233	209	190	16	22	862
SMUs 68-73	24	109	167	425	460	235	200	239	-	1,858
SMUs 74-79	22	93	38	81	20	20	27	128	-	430
SMUs 80-85	21	30	71	183	73	4	2	-	-	385
SMUs 86-91	5	14	17	98	115	3	1	-	-	253
SMUs 92-97	7	34	34	119	60	1	-	-	-	256
SMUs 98-103	4	4	5	12	71	-	-	-	-	95
SMUs 104-109	9	8	15	26	94	-	-	-	-	151
SMUs 110-115	17	24	14	201	383	202	-	-	-	840
Reach Total	784	3,040	3,716	8,614	5,488	2,533	1,787	586	92	26,003

Notes: [shaded] Area of sediment remediation demonstration project.
WDNR, 1999b and Retec, 2002c.

Table 2-9. Statistical Summary of Chemicals of Concern

Reach	Chemical Parameter	Number Samples	Number Detects	Percent Detects	Minimum Detect	Maximum Detect	Arithmetic Mean	Geometric Mean
PCBs in µg/kg								
OU-2	Total PCBs	263	188	71%	0.34	77,444	4,589	362
OU-3	Total PCBs	652	542	83%	3	54,000	5,236	627
OU-4	Total PCBs	1023	947	93%	0.4	710,000	20,139	2,613
OU-2	Aroclor-1242	171	145	85%	4.4	51,000	3,937	495
OU-3	Aroclor-1242	498	440	88%	4.8	54,000	5,160	625
OU-4	Aroclor-1242	1012	938	93%	26	710,000	20,630	2,695
OU-2	Aroclor-1254	98	15	15%	4.6	340	378	83
OU-3	Aroclor-1254	275	61	22%	6	6,600	234	40
OU-4	Aroclor-1254	914	41	4%	13	3,300	456	74
OU-2	Aroclor-1260	97	2	2%	120	2,100	391	69
OU-3	Aroclor-1260	274	49	18%	46	1,600	139	31
OU-4	Aroclor-1260	914	81	9%	8.6	17,000	489	79
OU-2	Aroclor-1268	4	4	100%	70	110	93	91
OU-3	Aroclor-1268	146	57	39%	9.2	270	40	19
OU-4	Aroclor-1268	48	6	13%	50	1,100	119	43
OU-2	Cong-77	10	6	60%	0.77	160	22	3.1
OU-3	Cong-77	27	19	70%	2.4	89	18	5.8
OU-4	Cong-77	26	24	92%	1.9	85	13	5.6
OU-2	Cong-77/110	30	30	100%	0.73	1,400	126	34
OU-3	Cong-77/110	73	72	99%	0.4	620	134	46
OU-4	Cong-77/110	8	8	100%	2.8	89	41	31
OU-2	Cong-105	14	10	71%	0.44	180	27	4.1
OU-3	Cong-105	27	24	89%	0.94	54	14	6.2
OU-4	Cong-105	26	25	96%	0.79	23	5.7	3.1
OU-2	Cong-118	39	37	95%	0.56	590	58	14
OU-3	Cong-118	86	82	95%	0.49	270	65	28
OU-4	Cong-118	26	26	100%	1.4	46	13	6.9
OU-2	Cong-126	10	3	30%	0.05	2.50	0.50	0.17
OU-3	Cong-126	27	7	26%	0.03	0.79	0.64	0.34
OU-4	Cong-126	26	5	19%	0.03	0.27	0.24	0.07
Dioxins/Furans in µg/kg								
OU-3	2,3,7,8-TCDD	3	3	100%	0.000	0.007	0.000	0.000
OU-4	2,3,7,8-TCDD	12	1	8%	0.010	0.010	0.010	0.010
OU-3	2,3,7,8-TCDF	3	3	100%	0.032	0.117	0.060	0.060
OU-4	2,3,7,8-TCDF	12	10	83%	0.020	0.170	0.050	0.030
DDT in µg/kg								
OU-2	p,p'-DDT	10	1	10%	3.4	3.4	9.2	4.7
OU-3	p,p'-DDT	17	3	18%	5.1	20.0	14.2	9.4
OU-4	p,p'-DDT	35	2	6%	19.0	28.0	7.6	6.0
OU-2	p,p'-DDD	10	2	20%	1.0	1.7	8.9	4.1
OU-3	p,p'-DDD	23	5	22%	1.5	2.8	8.5	3.4
OU-4	p,p'-DDD	24	3	13%	1.2	4.5	7.2	5.3
OU-3	p,p'-DDE	22	4	18%	6.6	22.0	10.9	4.8
OU-4	p,p'-DDE	34	1	3%	1.9	1.9	6.3	3.6
Metals in mg/kg								
OU-2	Arsenic	10	6	60%	2.8	9.7	4.4	4.0
OU-3	Arsenic	23	21	91%	2.2	7.6	4.6	4.4
OU-4	Arsenic	107	81	76%	0.8	386	9.5	5.4
OU-2	Lead	10	10	100%	44	130	76	73
OU-3	Lead	23	23	100%	2	1,400	139	59
OU-4	Lead	107	107	100%	4	350	85	71
OU-2	Mercury	10	10	100%	0.17	2.10	0.77	0.56
OU-3	Mercury	146	142	97%	0.01	9.82	2.28	1.28
OU-4	Mercury	95	92	97%	0.10	7.70	1.04	0.79

Retec, 2002c.

Table 2-8. Lower Fox River Stream Velocity Estimates (fps)

Deposit/SMU	Cross-Sect. Area (sf)	100 Year Low (141 cfs)	10 Year Low (883 cfs)	Average Flow (4,300 cfs)	10 Year Peak (19,200 cfs)	100 Year Peak (24,000 cfs)
OU-2						
DD	7,027	0.21	1.41	6.71	29.31	36.73
	OU-2 Average	**0.28**	**1.77**	**8.48**	**37.43**	**46.97**
OU-3						
EE-Upper	10,201	0.14	1.06	4.59	20.13	25.43
EE-Upper-Mid	11,642	0.14	0.71	3.88	17.66	22.25
EE-Lower-Mid	10,943	0.14	1.06	4.24	18.72	23.66
EE-Lower	10,609	0.14	1.06	4.24	19.42	24.37
GG/ HH	10,641	0.14	1.06	4.24	19.42	24.37
	OU-3 Average	**0.14**	**1.06**	**4.24**	**19.07**	**24.01**
OU-4						
SMU 20-25	18,594	0.07	0.71	2.47	10.95	13.77
SMU 25-31	12,084	0.14	0.71	3.88	16.95	21.54
SMU 32-37	13,751	0.11	0.71	3.53	15.19	18.72
SMU 38-43	16,947	0.11	0.71	2.83	12.36	15.19
SMU 44-49	20,003	0.07	0.35	2.47	10.24	13.07
SMU 50-55	15,699	0.11	0.71	2.83	13.07	16.60
SMU 56-61	20,519	0.07	0.35	2.12	10.24	12.71
SMU 62-67	20,056	0.07	0.35	2.47	10.24	12.71
SMU 68-73	20,552	0.07	0.35	2.12	9.89	12.71
SMU 73-79	19,389	0.07	0.35	2.47	10.59	13.42
SMU 80-85	14,892	0.11	0.71	3.18	13.77	17.30
SMU 86-91	16,387	0.11	0.71	2.83	12.71	15.89
	OU-4 Average	**0.11**	**0.71**	**2.83**	**12.36**	**15.19**

WDNR, 1995.

Table 2-7. Lower Fox River Discharge Data

Summary Statistics:

	Rapide Croche 1918-1997		Fox River Mouth 1989-1999	
	Discharge (m^3/s)	Discharge (cfs)	Discharge (m^3/s)	Discharge (cfs)
Daily Average	122	4,314	141	4,999
Daily Maximum	680	24,000	957	33,800
Daily Minimum	4	138	-92	-3,260
Monthly Maximum	206	7,286	215	7,580
Monthly Minimum	74	2,609	92	3,256
10th Percentile	--	--	54	1,920
50th Percentile	--	--	114	4,040
90th Percentile	--	--	272	9,610

Monthly Statistics:

	Rapide Croche 1918-1997			
	Average (m^3/s)	Average (cfs)	Minimum (m^3/s)	Maximum (m^3/s)
January	116	4,082	31	269
February	117	4,126	30	340
March	146	5,156	25	603
April	206	7,286	22	680
May	171	6,048	23	669
June	137	4,821	17	603
July	96	3,372	18	530
August	74	2,609	4	419
September	81	2,872	8	510
October	94	3,315	6	516
November	116	4,084	15	445
December	115	4,043	32	363

Data are from USGS gauging station #04084500 at the Rapide Croche Dam and the USGS acoustic velocity meter at the Fox River mouth.

Table 2-6. Summary of Physical Properties

Deposit, Interdeposit, SMU	Dry Bulk Density (pcf)		Wet Density (pcf)	Average TOC (%)		Specific Gravity		Avg Total Solids (%) [g]	Moisture Content (%) [h]
Source	***WDNR (1999)*** [a]	***Retec (2002)*** [b]	***Retec (2002)*** [b]	***WDNR (1999)*** [a]	***Retec (2002)*** [c]	***Retec (2002)*** [b]	***J. Co (2004)*** [e]	***Retec (2002)*** [d]	
OU -2 Appleton to Little Rapids Reach									
Deposit DD	39.95	*40.35* *	NA	4.4%	3.9%	*NA*		44.6%	124.2%
								26.0%	284.6%
Reach Average		***40.35***		4.38%	3.89%	***NA***		***35.3%***	***204.4%***
OU 3 - Little Rapids to DePere Reach									
Deposit EE	33.71	31.48 *	72.67 *	5.8%	5.6%	2.47 *		37.1%	169.8%
Deposit EG	NA	39.49 *	NA	NA	NA	NA		42.6%	134.7%
Deposit FF	22.47	45.23 *	NA	5.9%	4.9%	NA		45.1%	121.5%
Deposit GG	24.35	29.86 *	NA	6.5%	5.9%	NA		36.4%	175.0%
Deposit HH	36.83	33.33 *	NA	6.0%	6.4%	NA		36.7%	172.5%
Reach Average	***29.34***	***31.74***	***72.67***	***6.0%***	***5.7%***	***2.47***		***39.6%***	***154.7%***
OU 4 - DePere to Green Bay Reach									
SMU 20 to 25	47.76 *	37.46 *	71.79 *	4.4% *	5.1%	2.32 *	2.60 *	NA	
SMU 26 to 31	50.05 *	NA	NA	3.0% *	3.7%	NA	2.51	NA	
SMU 32 to 37	48.90 *	21.23 *	NA	4.1% *	5.6%	NA		NA	
SMU 38 to 43	48.49 *	31.12 *	NA	3.6% *	4.6%	NA		NA	
SMU 44 to 49	36.00 *	37.06 *	75.54 *	4.9% *	4.7%	2.4 *	2.54 *	NA	
SMU 50 to 55	42.03 *	34.52 *	NA	4.3% *	3.7%	NA		NA	
SMU 56 to 61	36.00 *	40.58 *	NA	5.4% *	5.7%	NA	2.48	NA	
SMU 62 to 67	39.64 *	NA	NA	5.6% *	6.6%	NA		NA	
SMU 68 to 73	35.58 *	24.66 *	NA	5.8% *	5.1%	NA		NA	
SMU 74 to 79	47.34 *	44.32 *	NA	4.1% *	5.1%	NA		NA	
SMU 80 to 85	47.45 *	NA	NA	4.6% *	5.3%	NA		NA	
SMU 86 to 91	54.83 *	48.90 *	NA	4.3% *	4.7%	NA		NA	
SMU 92 to 97	46.30 *	38.39 *	NA	4.0% *	2.8%	NA		NA	
SMU 98 to 103	69.82 *	NA	NA	1.9% *	2.1%	NA		NA	
SMU 104 to 109	52.78 *	39.02 *	NA	2.2% *	2.9%	NA		NA	
SMU 110 to 115	41.41 *	31.06 *	NA	5.0% *	4.7%	NA		NA	
Reach Average	***46.35*** *	***35.14*** *	***73.66*** *	***4.2%*** *	***4.5%***	***2.36*** *	***2.53*** *	***41.2%***	***142.7%***
OUs 3 and 4 Average [f]	**45.24** *	**32.46** *	**72.83** *	**4.3%** *	**4.7%**	**2.46** *	**2.53** *	**40.5%**	**149.6%**

Notes:

(a): Technical Memorandum 2E-1, Table B-1 (WDNR 1999)

(b): Lower Fox River Remedial Investigation Report, Appendix G, Table 7 (Retec 2002)

(c): Lower Fox River Remedial Investigation Report, Appendix G, Table 5 (Retec 2002)

(d): Lower Fox River Remedial Investigation Report, Appendix G, Table 6 (Retec 2002)

(e): Lower Fox River Geotechnical and Chemical Partitioning Study (Johnson Co. et al. 2004)

(f): OUs 3 and 4 Average includes Deposit DD from OU 2.

(g): Total solids expressed as percentage of total weight

(h): Moisture content calculated from total solids by weight

* Denotes values presnted in tables is average of data from original source(s).

Table 2-5. Atterberg Limits - Lower Fox River

Deposit or SMU	Sample Label	Sample Depth (cm)	Liquid Limit	Plastic Limit	Plasticity Index	USCS Classification
OU 3 - Little Rapids to De Pere Reach						
Deposit EE	GT0125	0 - 182.9	73.2	36.6	36.6	na
Deposit EE	SDC-EE22-3-G	5 - 35	61.3	30.3	31.0	CH
Deposit EE	SDC-EE22-4-G	5 - 35	85.0	45.1	39.9	MH
Deposit EE	SDC-EE23-1-G	5 - 35	na	Non-Plastic	na	na
Deposit EE	SDC-EE23-4-G	5 - 35	144.0	45.9	98.1	MH
Deposit EE	SDC-EE24-1-G	5 - 35	92.5	45.2	47.3	MH
Deposit EE	SDC-EE24-3-G	5 - 32	76.6	39.7	36.9	MH
Deposit EE	SDC-EE25-2-G	5 - 35	93.4	50.0	43.4	MH
Deposit EE	SDC-EE25-3-G	5 - 35	176.7	113.4	63.3	MH
Deposit EE	SDC-EE26-2-G	5 - 35	88.8	48.5	40.3	MH
Deposit EE	SDC-EE26-5-G	5 - 35	89.5	44.0	45.5	MH
Deposit GG	GT0068	0 - 182.9	89.4	45.1	44.3	na
Deposit HH	GT0079	0 - 182.9	85.4	44.5	40.9	na
OU 4 - De Pere to Green Bay Reach						
SMU 20	GT0005	0 - 173.7	94.3	47.0	47.3	na
SMU 20	SDC-DPD-2-G	5 - 35	95.0	49.5	45.5	MH
SMU 24	GT0013	0 - 185.9	97.3	53.0	44.3	na
SMU 41	GT0036	0 - 182.9	37.7	21.5	16.2	na
SMU 45	GT0048	0 - 195.1	68.9	33.5	35.4	na
SMU 45	SDC-DPD-3-G	5 - 35	156.9	109.6	47.3	MH
SMU 48	GT0040	0 - 182.9	44.6	23.6	21.0	na
SMU 62	GT0052	0 - 213.4	89.0	47.6	41.4	na

Notes:

1. Atterberg Limits testing performed according to ASTM D-4318.
2. Samples listed as non-plastic could not be cut with the grooving tool without tearing or slipping in the cup. Every effort was made to test these samples, but a liquid limit could not be determined.

3. Classifications are based on ASTM D-2487. The samples were visually determined to be organic. Samples classified as "na" were not determined by the laboratory.

Source: Lower Fox River Remedial Investigation Report, Appendix G, Table 3 (Retec 2002)

Table 2-4. Summary of Grain Size Data

Deposit, Interdeposit, SMU	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand/Gravel (%)	Silt/Clay (%)
Source	***WDNR (1999)*** [(a)]			***Retec (2002)*** [(b)]			***Johnson Co. et al. (2004)*** [(c)]	
OU -2 Appleton to Little Rapids Reach								
Deposit DD	32.0	43.0	25.0	32.6	42.1	25.3		
OU 3 - Little Rapids to DePere Reach								
Deposit EE	33.0	47.0	20.0	26.8	49.7	23		
Deposit FF	3.0	62.0	34.0	27.2	51.6	21.1		
Deposit GG	24.0	56.0	20.0	18	57.6	23.1		
Deposit HH	23.0	55.0	22.0	21.7	57.1	18.4		
Reach Average	***45.7***	***35.7***	***18.6***	***23.4***	***54.0***	***21.4***		
OU 4 - DePere to Green Bay Reach								
SMU 20 to 25	29.3	50.2	20.3	42.3	42.5	15.2	64.7	35.3
SMU 26 to 31	25.3	54.3	20.3	50.8	34.5	14.7	67.4	32.6
SMU 32 to 37	35.2	44.2	20.2	31.8	49.9	18.3	66.0	34.0
SMU 38 to 43	37.0	46.0	16.8	34.5	47.4	18.1		
SMU 44 to 49	35.0	48.2	16.8	37.8	44.6	17.6	47.5	52.5
SMU 50 to 55	28.2	55.5	16.5	40.5	44.2	15.3	37.3	62.8
SMU 56 to 61	31.5	48.7	19.8	32.1	51.9	16		
SMU 62 to 67	29.3	53.3	17.5	29.8	51.7	18.6		
SMU 68 to 73	31.3	51.7	17.2	34.8	41.6	23.1		
SMU 74 to 79	41.8	44.0	14.2	34.8	42.2	23		
SMU 80 to 85	42.2	43.3	14.7	45.4	36.8	17.8	20.5	79.5
SMU 86 to 91	28.0	52.3	19.5	45.5	37.6	17		
SMU 92 to 97	41.0	42.0	17.2	60.3	27.9	11.8		
SMU 98 to 103	52.2	32.7	15.0	73.2	17.8	9	75.5	24.5
SMU 104 to 109	45.7	37.0	17.3	41.7	40.5	17.8		
SMU 110 to 115	30.5	53.0	16.2	44.2	38.9	16.9		
Reach Average	***35.2***	***47.3***	***17.5***	***42.5***	***40.6***	***16.9***		
OUs 3 and 4 Average [(d)]	**34.6**	**47.5**	**17.8**	**38.4**	**43.2**	**18.1**	**54.1**	**45.9**

(a): Technical Memorandum 2E-1, Table B-1 (WDNR 1999)

(b): Lower Fox River Remedial Investigation Report, Appendix G, Table 1 (Retec 2002)

(c): Lower Fox River Geotechnical and Chemical Partitioning Study (Johnson Co. et al. 2004)

(c): OUs 3 and 4 Average includes Deposit DD from OU 2.

Table 2-3. Data Sources for Characterization of LFR Sediment Bed Properties

Data Source	Year Collected	Areas Sampled
WDNR, 1989 (Velleux and Endicott, 1994)	1989-1990	Depere Dam to Green Bay
WDNR, 1995	1989-1990	Lake Winnebago to Depere Dam
Graef, Anhalt, Schloemer, and Associates (GAS), 1996	1993-1994	4 Deposits: POG, D/E, N, EE/GG/HH
Woodward-Clyde/EWI, 1996	1991-1992	Deposit A
WDNR, 1998a	1993-94 1995	Depere Dam to Green Bay
WDNR, 1998b	1997	Deposit N, SMU 56/57
Foth and Van Dyke, 1998	1997	Deposit N
Montgomery Watson, 1998	1997	SMU 56/57

Note: Not all sources listed above pertain to Ous 3 and 4, or to Deposit DD in OU 2, for which this Remedial Design Work Plan has been prepared.

Table 2-2. Lower Fox River Locks and Dams

Lock	Lock Water Elevation		Dam	Dam Water Elevation		Distance Upstream	
	(meters*)	(feet*)		(meters*)	(feet*)	Km	Miles
Lake Winnebago	227.3	745.8		227.3	745.8	62.8	39.0
			Neenah Dam***	NA	NA	61.5	38.2
Menasha	227.3	745.8	Menasha Dam	227.3	745.8	59.5	37.0
Appleton Lock 1	224.4	736.1	Appleton Upper (Vulcan) Dam	224.4	736.1	51.3	31.9
Appleton Lock 2	221.9	728.1	Appleton Middle Dam***	NA	NA	50.9	31.6
Appleton Lock 3	218.5	716.8				50.4	31.3
Appleton Lock 4	215.5	707.0	Appleton Lower Dam	215.5	707.0	49.4	30.7
Cedars Lock	213.2	699.4	Cedars (Kimberly) Dam	213.2	699.4	43.9	27.3
Little Chute Guard Lock	210.2	689.6	Little Chute Dam	210.2	689.6	42.8	26.6
Little Chute Lock 2	210.2	689.6				42.5	26.4
Upper Combined Lock	206.0	676.0	Combined Locks	NA	NA	40.9	25.4
Lower Combined Lock	202.8	665.4				40.9	25.4
Kaukauna Guard Lock	199.2	653.5	Kaukauna Dam	199.2	653.5	38.6	24.0
Kaukauna Lock 1	199.2	653.5	Middle Kaukauna Dam***	Abandoned		38.0	23.6
Kaukauna Lock 2	196.1	643.2	Lower Kaukauna***	NA	NA	37.7	23.4
Kaukauna Lock 3	193.1	633.6				37.3	23.2
Kaukauna Lock 4	190.0	623.4				37.2	23.1
Kaukauna Lock 5	186.9	613.2				36.7	22.8
Rapide Croche Lock	183.7	602.8	Rapide Croche	183.7	602.8	30.9	19.2
Little Rapids(Little Kaukauna) Lock	180.9	593.5	Little Rapids(Little Kaukauna) Dam	180.9	593.5	21.1	13.1
De Pere Lock	179.0	587.4	De Pere Dam	179.0	587.4	11.4	7.1
Green Bay (River Mouth)	176.0	577.5	Green Bay (River Mouth)	176.0	577.5	0.0	0.0

Notes: Information obtained from the USACE and from the NOAA Recreational Atlas 14916 (1992).

* IGLD - International Great Lakes Datum, 1985

** Gradient values from upstream dam to this dam

*** Distance Upstream is Approximate; scaled from WDNR Dam Safety program interactive map (http://maps.dnr.state.wi.us/dams/viewer.htm)

NA: Not Available.

Table 2-1. Summary of Data Layers by Data Type

Vector Data	Raster Data	CADD Data
Bathymetric points from OSI survey	Bathymetry (interpolated)	Bathymetric point maps – OSI
Bathymetric points from USACE	Sediment thickness	Bathymetric point maps – OSI
Channel – dredged channel from USGS	Bulk density (WDNR interpolation)	River bottom and shoreline classifications
County boundaries	Contaminated thickness (WDNR interpolation)	
Dams	Mercury (WDNR interpolation)	
Demonstration project boundary	PCB concentration (WDNR interpolation)	
Hydrography – City of Green Bay	Sand, silt, clay percentage (WDNR interpolation)	
Hydrography – City of Green Bay mapping subset	Sediment thickness (WDNR interpolation)	
Municipal boundaries – Wisconsin	Total organic carbon (WDNR interpolation)	
Municipal boundaries – Lower Fox River	NOAA nautical charts for Lake Michigan	
Operating units – Lower Fox River	Velocities for different flow events modeled for OU 4 (LTI interpolation)	
Railroads – City of Green Bay	Bottom shear stresses for the different flow events modeled for OU 4 (LTI interpolation)	
Riverbed characterization	Bottom shear stresses for different wind events in the southern portion of OU 4 (LTI interpolation)	
Roads – City of Green Bay	Sediment thickness PCB concentrations >1 ppm (LTI interpolation)	
Roads – Wisconsin	Parameters observed in surface sediment sampling 2000 (LTI interpolation)	
Roads – Wisconsin highways	Digital elevation model of the Lower Fox River region (USGS provided)	
Sediment deposits	PCB Thickness based on Inverse Distance Weighting for OU3	
Sediment management units – OU 4	PCB Thickness based on Inverse Distance Weighting for OU4	
Shoreline – river and bay	Maximum PCB Concentration based on Kriging for OU3	
Lower Fox River shoreline (WDNR interpolation)	Maximum PCB Concentration based on Kriging for OU4	
All sample stations		
Sediment sample stations		
Tissue sample stations		
Water sample stations		
Other sample stations		
Surface sediment sampling points		
Potential Capping Areas		
Proposed Sample Locations		
Existing Core Locations		

Table 3-1. Landfill and Confined Disposal Facility Data Needs - Dewatered Sediment

RD Task (Data Gap)	Remedial Design Objective
Representative Sediment Properties Data Needs	
Total volume/tonnage TSCA and non-TSCA sediments	Air space design and evaluation of cell design options.
Grain size distribution and contaminant fraction analysis	Separate fine and coarse sediments for assessment of beneficial reuse options (for coarse sediments) and to assess impacts on landfill operation and evaluation of need for sediment amendments.
Total volume of oversize fractions	Impacts on landfill/CDF operation – separate or co-disposal of oversize fractions.
Percent solids dewatered sediments	Air space design and evaluation of cell design options.
Unconfined compressive strength versus moisture content	Operational design and operational, interim and long-term slopes.
Plastic and liquid limits of dewatered sediments	Trafficability and equipment compatibility.
Organic content of dewatered sediments	Trafficability, equipment compatibility and need for gas management.
Landfill Design and Operational Data Needs	
Short and long-term consolidation characteristics of dewatered sediments	Air space design, operational, interim and long-term slope design.
Permeability of dewatered sediments	Leachate collection system design an filling sequencing considerations.
Maximum density at "as disposed moisture content"	Trafficability, equipment compatibility and operational considerations.
Shear strength at operating sequences of landfill/CDF short-term and long-term consolidation	Landfill/CDF air-space, determination of operational, interim and final slopes.
Slope stability during short- and long-term consolidation	Sequence of cell filling and operation and leachate collection system design.
Landfill pre-design testing including: *Soil balance *Liner components	Evaluation of the landfill design components including: *Determine site suitability/usability *Define the soil and geosynthetic liner components *Land area required to support the infrastructure needed to support the landfill
Evaluation of leachate treatment *Leachability determinations (e.g., pore water chemistry, sequential batch leaching test (SBLT) and/or pancake column leach test (PCLT)	Available and implementable leachate treatment options. *Assess leachate and/or elutriate quality for water treatment options.