Volume I

Final
Basis of Design Report

Lower Fox River and Green Bay Site

Brown, Outagamie, and Winnebago Counties, Wisconsin

Prepared for:
Fort James Operating Company, Inc.
NCR Corporation

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BASIS OF DESIGN REPORT

LOWER FOX RIVER AND GREEN BAY SITE
BROWN, OUTAGAMIE, AND WINNEBAGO COUNTIES, WISCONSIN

Executive Summary

This Basis of Design Report (BODR) summarizes the results of the pre-design investigation of polychlorinated biphenyls (PCBs) in Operable Units 2 through 5 (OUs 2-5) of the Lower Fox River, delineates remediation areas, and describes remedial approaches and technologies. The subject area encompasses the Lower Fox River from the Appleton Locks to the mouth and the Bay of Green Bay (the "Site").

Following the 2003 Record of Decision (ROD) for the Site, a 2004 Administrative Order on Consent (AOC) was executed by the Fort James Operating Company, Inc. and NCR Corporation (collectively the "Participating Companies") in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency (collectively the "Response Agencies"). In the AOC, the Participating Companies agreed to design the remedy for the Site consistent with ROD requirements and where appropriate, to explore alternative remediation approaches. Throughout the remedial design (RD) process, the Response Agencies and Participating Companies have collaboratively and collectively addressed key technical and implementation issues through workgroups. During the RD process the Participating Companies and Response Agencies also addressed the contingent remedy provisions of the ROD and other remedial concepts, as provided under the AOC and the approved Remedial Design Work Plan (RD Work Plan).

This report includes a summary of new information collected and analyses conducted during the RD process to date. In developing the RD Work Plan, data available as of early 2004 were compiled and summarized to provide an assessment of current information on the extent of contamination and physical characteristics of the areas potentially subject to remediation. Data gaps identified from this review were addressed through extensive sampling in 2004 and 2005.

The RD investigation included collecting sediment cores at more than 1,300 locations and analyzing PCBs and physical parameters in more than 10,000 sediment samples. The RD investigation generated new sediment characterization data essential to the engineering design of the remedial action and included detailed bathymetric surveys (by WDNR), delineation of the 1 part-per-million (ppm) PCB sediment

boundary both horizontally and vertically, detailed hydrodynamic investigations and analysis, and physical characterization of sediments. The new information was used in performing engineering evaluations of sediment dredging, capping, handling, dewatering, water treatment, transport, disposal, and/or beneficial reuse options.

The new information collected during the RD investigation identified a number of site characteristics that are substantively different than those contemplated at the time of the ROD. Findings of the new data that are particularly relevant to RD include:

- PCB mass is not uniformly spread throughout the Site, but tends to be concentrated in smaller, definable areas.

- A small deposit of relatively highly contaminated near-surface PCBs has been identified downstream and west of the De Pere Dam.

- Deeply buried contaminated sediments are present at depth (between approximately 6 to 13 feet below mudline) below the bottom of the authorized federal navigation channel. Relatively cleaner sediments overlie these areas.

- Contaminated sediments were detected in several developed shoreline areas downstream of the De Pere Dam. In these areas, it may not practicable to dredge all buried contaminants because dredging could damage river banks and structures along the shore line. Based on the current and ongoing evaluations and data-gathering during RD, these nearshore areas may require engineered capping to achieve an implementable remedy that is protective of human health and the environment.

- Several contiguous areas within the Site, particularly in shallow water "bench" zones, are characterized by a relatively thin layer (often only 4 inches) of sediments that marginally exceed 1 ppm PCBs. While such lower-risk areas collectively represent only about 0.5 percent of the total PCB mass in the study area, they represent roughly 18 percent of the remedial action area.

- The limitations of modern dredging equipment in removing contaminated sediments have recently been documented. Post-dredge sediment residuals, which can make achievement of risk-based goals difficult in dredging-only remedies, are now understood as inevitable due to the inability of existing dredging equipment to remove all contaminated sediment within a dredge prism.

- There is limited landfill disposal capacity in Wisconsin, and no regional landfill individually has the capacity to accept the relatively large sediment disposal volumes that would be generated under the ROD Remedy.

This BODR evaluates different combinations of dredging, capping of specific areas, and other alternative remedial measures to address areas of sediment containing over 1 ppm PCBs and to achieve the required risk-based surface weighted average PCB concentration (SWAC), consistent with the ROD, AOC, and RD Work Plan. As detailed in this BODR, the ROD Remedy includes dredging of areas over 1 ppm PCBs, followed by placement of sand covers in approximately 50 to 60 percent of the dredged area to address any post-dredging low-level contamination that may remain. In addition, the ROD Remedy includes capping of certain areas over 1 ppm PCBs where side-slope, bulkhead, and utility requirements preclude dredging. The ROD Remedy also includes monitored natural recovery for most of the river between the Appleton Locks and Little Rapids Dam and in Green Bay, as set forth in the ROD.

Geostatistical analyses of the RD data were used to characterize the "neatline" boundary of sediments at the Site exceeding 1 ppm PCBs. This information was used to design the ROD Remedy dredge prism. The dredge prism represents the elevation, grades, and horizontal extent of sediment with concentrations greater than 1 ppm PCBs that a dredging contractor would be required to remove. In addition to the dredge prism, the RD incorporates an allowable overdepth for dredging. The allowable overdepth is a constant thickness of sediment below the required dredge prism to account for dredging equipment accuracy and tolerances. The dredge prism design utilizes multiple sets of data such as bathymetry, neatline depth and extent as defined by geostatistical methods, and constructability factors. Based on the RD data and analyses, the ROD Remedy dredge prism volume is approximately 7.6 million cubic yards (cy). This sediment volume is more than 1 million cy greater than the volume contemplated by the ROD.

This BODR also uses the considerable new information collected during RD to develop design components associated with an "Optimized Remedy." The Optimized Remedy builds on the ROD Remedy in that dredging would remove the bulk of the PCB mass in the river. While the Optimized Remedy is primarily a dredging action, it would remove a lower volume of sediment with PCB concentrations near or below the 1 ppm RAL, than the ROD Remedy. The Optimized Remedy also recognizes that because of dredge residuals or location-specific engineering, implementability, or practicability considerations, supplemental or alternative technologies must be applied to achieve the RAL and SWAC in some locations. The Optimized Remedy includes engineered capping in selected areas, consistent with the contingent remedy provisions of the ROD. Caps would be used only where permanent stability and performance can be assured, and without adversely affecting navigation (commercial or recreational), flood capacity, or habitat uses of the river.

Like the ROD Remedy, the Optimized Remedy uses sand covers for areas that have been dredged, to address any low-level residual contamination. In addition, the Optimized Remedy uses this sand cover technique to address certain non-dredged areas that have sufficiently low PCB concentrations and thicknesses to ensure protectiveness, such as areas where no more than one sediment sampling interval contains PCBs above 1 ppm and where the maximum PCB concentration is less than or equal to 2 ppm.

The Optimized Remedy applies these sand covers to specific areas of the Site based on the sediment conditions of those areas, as shown by the detailed new information collected during RD.

The Optimized Remedy also uses combinations of remedial technologies to achieve ROD goals, such as dredging to a specified elevation followed by placement of an engineered cap. The Optimized Remedy is designed to meet the risk-based SWAC goals and remedial timeframe set forth in the ROD and will address all sediment that exceeds 1 ppm PCBs. The Optimized Remedy also has been designed to maximize implementability, considering the constructability of different dredge and cap plans, the implementability of various transportation options, the availability of upland disposal facilities, and the feasibility of beneficial reuse opportunities.

The ROD Remedy and Optimized Remedy provide comparable levels of human health and environmental protection. The ROD predicted that the selected remedy would achieve acceptable fish tissue PCB concentrations within approximately 20 to 60 years following completion of construction, depending on the specific receptor. The Optimized Remedy is expected to achieve acceptable fish tissue PCB concentrations in a shorter time frame, primarily because it is expected to attain a lower post-construction SWAC within a shorter implementation period than the ROD Remedy. Both remedies are expected to comply with applicable or relevant and appropriate requirements (ARARs).

The dredge plan design for the ROD Remedy removes approximately 92 percent of the near-surface mass within the remedial action area and approximately 83 to 89 percent of the total mass of PCBs in this area. Dredged sediments (approximately 7.6 million cy) will be disposed of in off-site, upland landfills.

The dredge plan design for the Optimized Remedy includes many elements similar to the ROD Remedy dredge plan, but focuses dredging toward those areas where PCB mass removal can be more readily achieved, based on a core-by-core examination. Similar to the ROD Remedy, the Optimized Remedy is primarily a dredging action, and removes approximately 92 percent of the near-surface mass within the remedial action areas. The Optimized Remedy removes approximately 62 to 66 percent of the total mass of PCBs in this area, or roughly 74 percent of the total mass of PCBs that would be removed under the ROD Remedy. Under the Optimized Remedy, dredged sediments (approximately 3.7 million cy) can be disposed of in a single existing landfill.

Both the ROD Remedy and the Optimized Remedy are believed to be implementable, but the Optimized Remedy presents fewer uncertainties and implementability issues than the ROD Remedy, for reasons such as the following:

- Utilizing the new information from the sampling data, the Optimized Remedy focuses dredging on areas of higher PCB concentrations and available mass and uses other remedial techniques such as engineered capping to isolate and effectively remove PCBs from the environment in

lower risk areas. This results in a less complex dredge prism that is easier to implement from a dredging perspective, but includes a more complex combination of remediation technologies in some reaches of the river that requires careful planning and sequencing. The ROD Remedy dredge prism is significantly more complex and would be difficult to implement from a dredging perspective.

- The Optimized Remedy includes mechanical dewatering of dredged sediments to ensure that sufficiently high solids contents are achieved for landfill disposal, using processes similar to those implemented successfully during the earlier Fox River demonstration projects. At this scale, redundant dewatering equipment is planned to reduce operational uncertainty associated with mechanical dewatering. Due to the larger dredge volumes, the most effective material handling method for the ROD Remedy is pipeline transport with a passive dewatering basin. At the volume of the ROD Remedy, this combination has greater uncertainties and very few identified locations for the requisite dewatering basin (at any existing or proposed solid waste management facility). Other factors, such as varying dredge material physical characteristics and weather, also can affect the speed and effectiveness of a passive dewatering system. Any difficulties with dewatering will increase the duration and cost of the ROD Remedy.

- The lesser sediment disposal requirements associated with the Optimized Remedy allow for more transport options, including trucking, and a single regional landfill would probably be sufficient. The relatively large disposal requirements associated with the ROD Remedy would require a minimum of two separate landfill disposal facilities and pipeline transport. Depending on the specific site(s) targeted for disposal, uncertainties relating to necessary state and local approvals may extend the construction schedule. In addition, the pipeline easement negotiated by WDNR for possible use under the ROD Remedy is subject to termination under certain conditions. Because of the large sediment volumes involved, any unavailability of the pipeline to transport sediments over the life of the project would have a major impact on the schedule and cost of the ROD Remedy.

- The ROD Remedy assumes concurrent operation of 2 hydraulic cutterhead dredges discharging into a common receiving tank and single pipeline for transport. Such a transport system has not been implemented in any other environmental dredging project on the scale of the ROD Remedy, and its implementability under these circumstances is more uncertain than that of the single hydraulic cutterhead dredge anticipated to be used under the Optimized Remedy.

Engineered caps have been designed in both remedies with substantial margins of safety to ensure the permanent containment of contaminated sediments. The engineered caps provide protective and reliable chemical isolation that prevents erosion of the underlying sediment even in the face of major erosion events (e.g., floods, propeller wash, ice scour, and wind-waves).

To ensure the adequacy and reliability of controls for an in situ cap, a long-term monitoring, maintenance, and contingency response plan, including institutional controls and repair (as needed) of damaged capping areas, will be part of the Optimized Remedy. This is similar to controls normally included with upland landfill confinement options. The long-term cap monitoring plan will include both physical integrity monitoring (e.g., bathymetry surveys) and chemical analyses of surface sediments and cores collected from within the capped areas to verify the continued protectiveness of the caps over time. Many institutional controls necessary to ensure long-term cap integrity are already in place (e.g., no anchor zones in the navigation channels and operation and maintenance agreements for the De Pere Dam), and will be assessed further during later stages of design.

Vitrification was previously tested by the Response Agencies on a pilot scale. The results of these evaluations, and supplemental analyses performed during RD, revealed that large-quantity vitrification is not a cost-effective alternative.

In summary:

- Both remedies provide overall protection of human health and the environment and comply with ARARs. The remedies also provide comparable levels of long-term effectiveness, permanence, and reduction of toxicity, mobility and volume.

- The ROD Remedy relies on dredging as the primary remedial action and, due to the very large volumes involved, has transport and dewatering uncertainty. The ROD Remedy will also consume a large amount of the existing landfill capacity. The Optimized Remedy also relies on dredging as the primary remedial action, but uses a combination of remedial actions that reduce the dredged volume (particularly of sediments at or near the RAL) and requires less landfill capacity.

- The ROD Remedy will require 15 or more years to complete. The Optimized Remedy can be completed in 9 years, providing more short-term effectiveness. The Optimized Remedy will also achieve the long term objective of acceptable fish tissue PCB concentrations and will do so more quickly than the ROD Remedy.

- The ROD Remedy is estimated to cost $580 million. The Optimized Remedy is estimated to cost $390 million.

A summary of the elements of the ROD Remedy and Optimized Remedy is presented in Table ES-1. A summary of the comparative evaluation of the two remedies under the National Contingency Plan (NCP) remedy selection criteria is presented in Table ES-2. Through its presentation of the RD investigation results and the basis of design for both the ROD Remedy and the Optimized Remedy, the BODR achieves the goals and satisfies the requirements of the AOC, the RD Work Plan, and the ROD.

Table ES-1. Summary of Lower Fox River Remedial Design Scenarios

Component	Units	ROD Remedy	Optimized Remedy
1. Prospective TSCA Dredging and Disposal			
a. Estimated Dredge Volume (OU 4)	*in situ* cy	210,000	200,000
b. Dredging Method	-	Mechanical	Hydraulic Cutterhead
c. Dewatering Method	-	Amendment	Mechanical Press
d. Assumed Handling Facility	-	GP/Shell Property	GP/Shell Property
e. Assumed Off-Site Transport Method	-	Truck	Truck
f. Assumed Disposal Facility	-	EQ Wayne Disposal (MI)	EQ Wayne Disposal (MI)
g. Alternate Disposal Facility	-	Peoria Disposal Company (IL)	Peoria Disposal Company (IL)
2. Non-TSCA Dredging and Disposal			
a. Estimated Dredge Volume (with overdredge)			
OU 2	*in situ* cy	81,000	24,000
OU 3	*in situ* cy	716,000	204,000
OU 4	*in situ* cy	6,552,000	3,258,000
Total	*in situ* cy	7,349,000	3,486,000
b. Dredging Method	-	2 Hydraulic Cutterheads	1 Hydraulic Cutterhead
c. Desanding Method	-	Desanding/Flotation/Attrition Scrubbing	Desanding/Flotation/Attrition Scrubbing
d. Estimated Separated Sand Volume	cy	530,000	225,000
e. Assumed Desanding/Storage Facility	-	GP/Shell Property	GP/Shell Property (w/ shoreline fill)
f. Off-Site Sediment Transport Method	-	Mixing Tank / Pipeline	Truck
g. Estimated Disposal Wt. (dewatered)	*tons*	5,604,000	1,815,000
h. Assumed Dewatering Method	-	NR 213 Basin at Brown County South	Mechanical Press
i. Assumed Disposal Facility	-	Brown County South AND Onyx	Onyx Hickory Meadows
k. Alternate Transport Method	-	N/A	Pipeline (w/out mixing tank)
l. Alternate Dewatering Method	-	Dewatering Landfill	Dewatering Landfill
m. Alternate Disposal Facility	-	VandeHey	Brown County South or VandeHey
n. Average Production Rate	*in situ* cy/day	4,790	3,190
o. Approximate Dredging Duration	years	11 to 15	8
3. Beneficial Use of Separated Sand			
a. Estimated Beneficial Use Volume	cy	530,000	225,000
b. GP/Shell Staging Facility Fill	cy	20,000	150,000
c. Post-Remedy Staging Area Use	-	Site redevelopment & wharf use	Site redevelopment & wharf use
d. Non-Remedial Beneficial Use Volume	cy	510,000	75,000
e. Non-Remedial Beneficial Use Options	-	See Section 4.3	See Section 4.3
4. Sediment Caps and Covers			
a. Target Sand Volume	cy	660,000 (primarily residual cover)	890,000
b. Target Gravel Volume	cy	65,000 (shoreline caps)	390,000
c. Target Quarry Spalls Volume	cy	0	20,000
d. Transport and Placement Method	-	Barge & Rehandling Bucket	Barge & Rehandling Bucket
5. Overall Performance Metrics			
a. Total Project Duration	years	15 +	9
b. OU 3 / OU 4 SWAC	ppm PCBs	< 0.26 / < 0.25	< 0.26 / < 0.25
c. Near-Surface PCB Mass Removed	%	92%	92%
d. Total PCB Mass Remediated	%	99%	99%
e. Total PCB Mass Removed	%	83 to 89%	62 to 66% (74% of ROD Remedy removal)
f. Total Cost	Present worth	$580 million	$390 million

Table ES-2. Evaluation Criteria Comparison

CERCLA Criteria	ROD Remedy	Optimized Remedy
1. Overall Protection of Human Health	YES – Acceptable risks achieved 20 to 60 years after completion of remedial actions, depending on the receptor. Long-term monitoring plan (and maintenance and contingency response plan for shoreline capping) to ensure protectiveness.	YES - Acceptable risks achieved 20 to 60 years after completion of remedial actions, depending on the receptor. Long-term monitoring, maintenance, and contingency response plan to ensure protectiveness.
2. Compliance with ARARs	YES - Expected to meet ARARs	YES – Expected to meet same ARARs as ROD Remedy plus additional ARARs regarding capping.
3. Long-Term Effectiveness and Permanence	YES - Requires some degree of institutional controls (i.e., fish consumption advisories until the remedial action objectives are met). ROD Remedy removes approximately 92 percent of near-surface PCB mass in OU 2 to 5 project area sediments. Nearshore areas that cannot be dredged without adverse impacts to shoreline structures will be permanently contained below engineered caps.	YES - Requires some degree of institutional controls (i.e., fish consumption advisories until the remedial action objectives are met). Optimized Remedy removes approximately 92 percent of near-surface PCB mass in OU 2 to 5 project area sediments. Overall, the Optimized Remedy removes approximately 74 percent of the PCB mass targeted for removal under the ROD Remedy. Remaining sediment with PCB concentrations greater than 1 ppm will be permanently contained.
4. Reduction of Toxicity, Mobility, or Volume through Treatment	YES - Overall mobility reduction through upland containment. Possible treatment of approximately 210,000 cy of sediments potentially subject to TSCA disposal requirements, pending verification of performance, implementability, and cost-effectiveness.	YES – Overall mobility reduction through a combination of upland and cap containment. Possible treatment of approximately 200,000 cy of sediments potentially subject to TSCA disposal requirements, pending verification of performance, implementability, and cost-effectiveness.
5. Short-Term Effectiveness	YES - Project duration estimated to range from 15 to 24 years, depending on difficulties encountered with concurrent operation of 2 dredges, and the time required to obtain pipeline easements and landfill disposal agreements (see Section 6.2).	YES - Project duration estimated to be approximately 9 years (see Section 6.3). Shorter period of construction water quality impacts and other construction-related impacts.
6. Implementability	YES - Services, materials, and equipment are locally available (except hydraulic dredges). However, landfill capacity is limited (at least 2 separate NR 500 landfills will be required for disposal). Necessary pipeline easements are also uncertain. Operational difficulties of two dredges to a common pipeline are also uncertain. Capping included in ROD Remedy near shoreline structures and utilities.	YES - Services, materials, and equipment are locally available (except hydraulic dredges). Smaller sediment disposal volume allows more transport and landfill options (only one of several existing and/or potential future NR 500 landfills required). Capping included in Optimized Remedy near shoreline structures and utilities, and in other areas of the site to optimize the remedy.
7. Cost (in millions of dollars)	$580 million (see Section 8.2)	$390 million (see Section 8.3)
8. Agency Acceptance	ROD Remedy was previously selected by EPA and WDNR, though certain changes to the remedy as described in this BODR are contingent upon approval from EPA and WDNR through an ESD or ROD Amendment.	Contingent upon approval from EPA and WDNR through an ESD or ROD Amendment.
9. Community Acceptance	Prior public opposition to pipeline easements and landfill disposal in certain locations.	Public comments will be solicited through ESD or ROD Amendment process.

FINAL
BASIS OF DESIGN REPORT

LOWER FOX RIVER AND GREEN BAY SITE
BROWN, OUTAGAMIE, AND WINNEBAGO COUNTIES, WISCONSIN

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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
ASTM	American Society of Testing and Materials
AVM	Acoustic velocimeter
BACT	Best Available Control Technology
BMP	best management practice
BOD	biological oxygen demand
BODR	Basis of Design Report
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
COC	contaminant of concern
CPT	cone penetrometer testing
CQAP	Construction Quality Assurance Plan
CST	column settling test
CU	consolidated undrained (triaxial test)
cy	cubic yard
DEA	Detailed Evaluation of Alternatives
DMR	Discharge Monitoring Reports
DO	dissolved oxygen
DOC	depth of contamination
DL	detection limit
DRET	Dredging Elutriate Test
EDD	Electronic Data Deliverable
ERR	Ecosystem Restoration Report
ES	Enforcement Standards
ESD	Explanation of Significant Difference
FGDC	Federal Geographic Data Committee
FIK	Full Indicator Kriging

Fort James	Fort James Operating Company, Inc.
fps	feet per second
FRVOR	Fox River Valley Organic Recycling
FRDB	Fox River Database
FRG	Fox River Group
FS	feasibility study
GBMBS	Green Bay Mass Balance Study
GIS	Geographic Information System
GLNPO	Great Lakes National Program Office
GFT	gas furnace technology
GP	Georgia Pacific
GPS	global positioning system
gpm	gallons per minute
HAP	hazardous air pollutant
HASP	Health and Safety Plan
HDPE	high density polyethylene
IDW	inverse-distance-weighted
IGLD	International Great Lakes Datum
lb	pound
lb/hr	pounds per hour
LDD	Land Development Desktop
LTA	long-term average
LTI	Limno-Tech, Inc.
LOS	level of significance
MAD	Mean Absolute Deviation
MET	Modified Elutriate Test
mg/L	milligram per liter
MNR	Monitored Natural Recovery
MS	matrix spike
MU	management units
MSW	municipal solid waste
NAVD	North American Vertical Datum
NCP	National Contingency Plan
NCR	NCR Corporation
ng/l	nanograms per liter

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
PCB	polychlorinated biphenyl
PCLT	pancake column leach test
ppm	part per million
PRP	Potential Responsible Party
psf	pounds per square foot
psi	pounds per square inch
QAPP	Quality Assurance Project Plan
QC	quality control
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RI	remedial investigation
RM	river mile
RMSE	root mean square error
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SAV	submerged aquatic vegetation
Shaw	Shaw Environmental & Infrastructure, Inc.
SEI	Sea Engineering, Inc.
SICT	seepage-induced consolidation test
SLOH	State Lab of Hygiene
SMU	sediment management unit
SOW	Statement of Work
SPT	Standard Penetration Test
STL	Severn Trent Laboratories, Inc.
SWAC	surface-weighted average concentration
TBD	to be determined
TCLT	thin-layer column leach test
TIN	triangulated irregular network

TM2D	Technical Memorandum 2d
TM3a	Technical Memorandum 3a
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TSS	total suspended solids
µm	micrometer
µg/kg	microgram/kilogram
µg/L	microgram/liter
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USCS	United Soil Classification System
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UU	unconsolidated undrained (triaxial test)
VST	vane shear test
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollution Discharge Elimination System
WRDA	Water Resources Development Act
WTM	Wisconsin Transverse Mercator
WWTP	waste water treatment plant
ZID	zone of initial dilution

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1. INTRODUCTION

1.1 Purpose

This Basis of Design Report (BODR) presents delineations of remediation areas and technologies for cleanup of polychlorinated biphenyls (PCBs) in Operable Units (OUs) 2, 3, 4 and 5 of the Lower Fox River and Green Bay Site (Site; Figure 1-1). The PCB cleanup remedy for the Lower Fox River is set forth in Records of Decision (RODs) for OUs 2 to 5 signed by WDNR and USEPA in December 2002 and June 2003. The requirements for the BODR are set forth in the Administrative Order on Consent (AOC) and associated Statement of Work (SOW) for OUs 2 to 5 (USEPA 2004), executed in March 2004 by Fort James Operating Company, Inc. (Fort James) and NCR Corporation (NCR) (collectively the "Participating Companies") in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency Region 5 (USEPA) (collectively the "Response Agencies"). The requirements for this BODR are more specifically described in the Remedial Design Work Plan (RD Work Plan), approved by the Response Agencies on June 28, 2004. The RD Work Plan and this BODR address only OUs 2 to 5. The remedial design of OU 1 is being addressed under a separate agreement between WDNR, USEPA, and the WTM1 Company.

As set forth in the AOC, the Participating Companies have agreed to design the remedy for OUs 2 to 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 ongoing remedial design (RD) is addressing the timing and sequencing of the remedial action to account for the multifaceted and multi-year components of the remedy. The Response Agencies and Participating Companies have collaboratively sought to resolve key technical and implementation issues through the timely use of workgroups and other communications. The Participating Companies and Response Agencies have also incorporated into the RD process the contingent remedy provisions of the ROD and other remedial concepts, as provided under the AOC and the RD Work Plan.

This BODR includes a summary of information collected and analyses conducted during initial RD phases, along with other data available for the Lower Fox River Site (e.g., OU 1 work information), and appropriate literature and design references. This report also includes updated removal, dewatering, transportation, treatment, and disposal options. For each option, updated implementability evaluations and cost estimates were developed based on new information revealed by the sampling and analysis of prospective remedial areas conducted as part of this RD. This BODR provides a delineation of the volume and area of sediments addressed by the dredging and capping recommendations, along with associated technical justifications.

The conceptual designs contained in this BODR are subject to approval by the Response Agencies. The Response Agencies will select the appropriate remedial design options based on the approved BODR, consistent with the RODs for OUs 2 to 5 and including an Explanation of Significant Differences (ESD) or ROD Amendment, as appropriate.

1.2 Site Description

The Lower Fox River extends 39 miles from the outlet of Lake Winnebago to the mouth of the river where it discharges into Green Bay (Figure 1-1). The Lower Fox River is the most industrialized river in Wisconsin; since the early 1900s, water quality has been degraded by expanding industries and communities discharging sewage and industrial wastes into the river. PCBs were discovered in the Lower Fox River in the 1970s. As set forth in the RODs, PCBs are the focus of current remedial design efforts.

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. The OU 1 to 2 ROD calls for active remediation in Deposit DD only, while monitored natural recovery (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.
- 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 U.S. Army Corps of Engineers (USACE). 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 OU 3 to 5 ROD calls for MNR as the selected remedy for OU 5, with the exception of potential dredging near the River mouth following additional sampling.

1.3 Remedial Design Approach

This BODR is intended to achieve an expedited cleanup of OUs 2 to 5 that builds on prior work, is protective of human health and the environment, is consistent with the National Contingency Plan (NCP), complies with the RODs, AOC/SOW and RD Work Plan, and is cost-effective. This BODR has been developed through a collaborative and cooperative process between the Response Agencies

and Participating Companies. The parties have met and conferred on a regular basis and have sought to anticipate and resolve key issues in advance of submittal of this document. The collaborative process is ongoing.

Remediation work in OU 1 has been initiated, and will likely continue to precede remediation efforts in OUs 2 to 5. Also, pilot and/or early action projects have been and may continue to be implemented in one or more OUs (including OU 1) before certain components of the remedy are implemented on a site-wide, full-scale basis. The BODR process has also incorporated information and experience from remedial efforts that have been completed to date (e.g., the Sediment Management Unit [SMU] 56/57 and Deposit N dredging demonstration projects), as well as the work, tasks, projects and investigations that have been undertaken as the RD has progressed.

The RD Work Plan concluded that various Water Resources Development Act (WRDA) authorities overlap with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial design requirements, and also recognized that there may be an opportunity for WDNR to integrate the CERCLA action with other complementary efforts.

As set forth in the AOC/SOW (USEPA 2004) and the RD Work Plan, the RD for OUs 2 to 5 consists of the following tasks:

I. Remedial design planning;
II. 2004 and 2005 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 BODR incorporates the results of initial remedial design planning, as presented in the RD Work Plan. Existing data available as of 2003 for OUs 2 to 5, including limited sampling data collected after the RODs were issued, were compiled into a suitable geographic information system (GIS) platform to provide an initial assessment of the extent of contamination and physical characteristics of the river channel and side-slope areas. These existing data were used to identify RD data gaps and develop the RD Work Plan. This BODR uses such existing information, along with the more extensive remedial design data collected during the 2004 and 2005 sampling and analysis programs, to inform the RD. As described in more detail in Section 2.1, RD data collection included baseline surveying, delineation of the extent of PCB contamination both horizontally and vertically, assessment of chemical mobility, and physical characterization of sediments as needed to assess the application of specific remediation technologies, including beneficial uses. Additionally, information

on future land use planning, including reauthorization by Congress of portions of the Lower Fox River federal navigation channel, has been compiled.

The review and analysis of Site data is presented in initial sections of this document and forms the basis for development of this BODR, while subsequent sections discuss how each component of the RD will be addressed, including phases, tasks, and sequencing. This BODR also presents preliminary project cost estimates, construction schedules, and sequencing for major activities.

1.4 Cleanup Levels and Performance Standards

The remedy selected in the RODs for the Lower Fox River includes dredging of sediment within parts of OUs 2 to 5, particularly OUs 3 and 4, that contain PCB concentrations greater than the 1 part-per-million (ppm) remedial action level (RAL). The ROD Remedy specifies the use of dredging methods that minimize environmental impacts, followed by dewatering and off-site disposal of the sediment. The ROD Remedy also provides for placement of an approximately 6-inch layer of sand, as needed, on the dredged surface to control dredge residuals. The selected remedy for the remainder of the Site area, including most of OU 2 and OU 5, is MNR with institutional controls.

The ROD for OUs 3 to 5 provides that even if not all sediment containing more than 1 ppm PCBs can be removed, the remedial action will be considered complete if, after remedial actions are conducted, the surface-weighted average PCB concentration (SWAC) meets the remedial action objectives (RAOs) of 0.26 ppm for OU 3 and 0.25 ppm for OU 4. Post-construction sampling will be conducted to determine if the RAL or SWAC have been achieved. The SWAC will be computed following completion of dredging and/or cover construction, 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 and covered areas to represent area-wide exposures to humans or wildlife. The SWAC calculation procedure is discussed further in Section 7 of this BODR, with details of confirmation sampling and adaptive management to be provided as part of forthcoming design submittals.

Plans for long-term monitoring of various media (e.g., water, tissue, and sediment) to determine the effectiveness of the overall remedy will be developed during RD. Baseline monitoring is currently scheduled to begin in April 2006, subject to approval by the Response Agencies of the Baseline Monitoring Work Plan and accompanying Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP). Monitoring during implementation of the remedy will include surface water sampling and may include air sampling. Plans for monitoring during and after construction will be developed during RD and may be modified during and after construction, as appropriate. A long-term monitoring and institutional control plan will be developed as part of RD.

As discussed further below; combinations of dredging, capping of certain areas, and other alternative remedial measures are being evaluated during RD to address areas of sediment containing over 1 ppm PCBs, consistent with the contingent remedy provisions of the RODs and the AOC and RD Work Plan. Regardless of the extent to which the remedy includes capping and other measures in addition to dredging, the remedy must still be designed to achieve the required SWAC.

1.5 Applicable or Relevant and Appropriate Requirements (ARARs)

ARARs for the remedial design are set forth in the RODs for OUs 2 to 5. The remedial design will be consistent with the ARARs listed in the RODs.

1.6 Remedial Design Options

Consistent with the RODs and AOC, this BODR defines volumes and areas to be dredged and identifies recommended dewatering, transportation, treatment, disposal, and beneficial use options. These recommended remedial design elements 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 construction schedule. This BODR provides:

- A demonstration that the design elements carried forward in this BODR meet the nine CERCLA evaluation criteria specified in the 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.

This BODR evaluates the ROD Remedy as set forth in the ROD for OUs 1 and 2 (as it applies to Deposit DD in OU 2) and the ROD for OUs 3-5. The RODs called for dredging of areas that exceed the 1 ppm RAL in Deposit DD, OU 3, OU 4, and an area of OU 5 adjacent to the mouth of the Fox River. As developed in more detail in this BODR, the ROD Remedy is defined to include the dredging called for in the RODs, as well as placement of post-dredge residual sand covers, which are discussed in the RODs. In addition, the ROD Remedy is defined in this BODR to include the use of engineered capping where side-slope, bulkhead, and utility requirements may preclude dredging, pending further evaluations during the RD. While not specifically spelled out in the RODs, this capping may be necessary to ensure that all areas that exceed the RAL are addressed, including areas that the RD demonstrates cannot be dredged practicably. Finally, the ROD Remedy includes MNR for most of OU 2 and OU 5, as set forth in the RODs.

In addition to the ROD Remedy, and in consideration of the criteria established in the ROD regarding a contingent remedy, this BODR makes use of the considerable new information collected during RD to further develop design components associated with an "Optimized Remedy." The Optimized Remedy builds on the ROD Remedy, in that it involves dredging to remove the bulk of the PCB mass in the river. At the same time, the Optimized Remedy avoids removing large volumes (over 2 million cubic yards) of sediment at or below the 1 ppm RAL, and recognizes the engineering and practicability constraints that prevent dredging alone from achieving the 1 ppm RAL at many locations. The Optimized Remedy includes engineered capping, consistent with the "contingent remedy" provisions of the RODs that is limited to specified areas in which it will provide the same protectiveness as the ROD Remedy. Like the ROD Remedy, the Optimized Remedy uses residual sand covers for certain areas where residual contamination remains following dredging. The Optimized Remedy also uses sand covers in selected areas with sufficiently low pre-dredging PCB concentrations and thicknesses to ensure their long-term protectiveness. The Optimized Remedy applies each of these remedial technologies to specific areas of the Site based on the sediment conditions of those specific areas, as shown by the new information collected during RD. Also like the ROD Remedy, the Optimized Remedy is designed to meet the SWAC goals set out in the RODs, meet the remedial timeframe set out in the RODs, and address all sediment that exceeds the RAL.

Each of these remedial design options is briefly outlined in the sections below. Subsequent sections of this BODR provide additional technical details of the two options, and compare and contrast the two approaches.

1.6.1 ROD Remedy

Within OUs 3 and 4, along with OU 2 Deposit DD and near the mouth of the Lower Fox River in OU 5, the ROD Remedy consists of removal of sediment with PCB concentrations greater than the 1 ppm RAL. As more specifically described in Sections 3 and 4 of this BODR, the ROD Remedy includes the following:

- **Site Mobilization and Preparation**. Staging areas will be required to support the remedial action. Site preparation at the staging areas will include design and baseline site characterization, securing onshore property area for equipment staging, and constructing the necessary onshore facilities, including wharf improvements as necessary for sediment management and transportation. Preparation for remedial actions also includes securing pipeline easements, dewatering basin and landfill permits, and disposal agreements.
- **Sediment Removal**. Sediment removal will be conducted using dredging equipment appropriate for site conditions and with suitable offsets (in some cases requiring localized caps) to avoid dredging-related impacts on nearshore facilities and other structures. A mechanical dredge will be used to remove sediments potentially subject to management under the Toxic Substances Control Act (TSCA), while hydraulic dredges will be used to remove remaining sediments exceeding the 1 ppm RAL. To complete sediment removal actions in a time frame as close as possible to the ROD objective of approximately 10 years,

two hydraulic dredges will work concurrently in OU 4 as practicable during seasonal dredging periods. Sediment removal will generally occur in an upstream-to-downstream sequence to minimize the potential for recontamination. Sediment removal will be coordinated with USACE navigation channel maintenance and environmental dredging actions as appropriate.

- **Sediment Desanding**. Bench-scale testing of OU 3 and 4 sediments performed during the RD evaluation demonstrated that relatively uncontaminated sand (less than the 1 ppm RAL) can be practicably separated from the more contaminated silt and clay materials. Initial removal of coarse material will precede pipeline transport of the remaining sediments to the disposal site, as generally described in the RODs. Accordingly, desanding of dredged sediments will occur at an upland processing facility prior to pipeline transport, to the extent that beneficial uses of particular volumes of the separated sand have been established. Separated sands will be beneficially used as practicable, primarily in off-site applications. Based on the observed grain sizes distribution in the sediment of the planned dredge prism, approximately 530,000 cubic yards (cy) of segregated sand is potentially available under the ROD Remedy, all of which is targeted for potential beneficial use. Mass balance and process calculations indicate that desanding will not result in TSCA-level concentrations in the remaining silt and clay fraction (see Appendix A). Monitoring of stockpiled materials will be performed in a manner similar to the SMU 56/57 Demonstration Project. (Monitoring details will be developed as part of the 60 Percent Design submittal.)

- **Sediment Dewatering, Pipeline Transport, and Disposal**. Sediments will be transported by pipeline to a passive dewatering basin or basins, engineered and constructed to Wisconsin Administrative Code NR 213 regulations. Following adequate dewatering in this basin(s), and amendment as necessary, the sediment will then be disposed of in one or more dedicated engineered landfills or other suitable disposal facilities, consistent with Wisconsin Administrative Code NR 500.

- **Water Treatment**. Treatment of water generated by the dredging, desanding, and dewatering operations, as well as all storm water collected from the upland staging facility, will be performed (as needed) to achieve performance standards set forth in the RODs. Water treatment may consist of flocculation, clarification, sand filtration, and treatment through activated carbon filters, prior to discharge of the waters back into the river.

- **In situ Capping of Shoreline Areas**. In situ capping of sediments exceeding the 1 ppm RAL may be performed along shoreline areas where RD engineering evaluations conclude that dredging would adversely affect the stability of the existing slopes. RD investigations will also include evaluation of impacts of potential dredging on structures in and adjacent to the river.

- **Post-Dredge Residual Management**. Owing to site characteristics and the limitations of modern dredging equipment, a relatively small fraction (typically 2 to 8 percent by weight) of the sediment and contaminant mass targeted for removal will likely settle back within and immediately adjacent to the dredge area as a contaminated surface layer with high water content. Management of these dredge residuals will likely be required to meet the overall SWAC goals specified in the RODs, and may include: placement of layers of sand on or immediately adjacent to the dredge surface, redredging where the consistency of the materials are suitable for cost-effective dredging, or other adaptive management options informed by the results of post-dredge sampling and analysis data.

- **Demobilization and Site Restoration**. Demobilization and site restoration will involve removing equipment from the staging and work areas and restoring the site substantially to its original condition. Staging area improvements (e.g., wharf construction) will be retained.
- **Natural Recovery, Monitoring, and Institutional Controls**. A long-term monitoring and institutional control plan will be developed as part of RD. Long-term monitoring will track recovery of sediment, water, and biological tissue concentrations following completion of the remedial action, relative to the general objective stated in the RODs of achieving risk-based targets over a multiple-decade recovery period. Institutional controls during and/or following the recovery period may include access restrictions, land use or water use restrictions, dredging moratoriums, and fish consumption advisories. Land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of contaminated areas.

The ROD Remedy design is described in more detail in Sections 3 and 4 of this BODR.

1.6.2 Optimized Remedy

The design goals of the Optimized Remedy were developed to achieve concurrently all of the following:

- Ensure achievement of the risk-based SWACs specified in the RODs in both the short and long term;
- Address all sediment with PCB concentrations above the 1 ppm RAL;
- Pursue PCB mass removal by dredging higher risk deposits identified within the Site, without removing large volumes of sediment that are near or below the 1 ppm RAL or that present other engineering feasibility or practicability issues;
- Design and apply engineered, armored caps, consistent with the contingent ROD remedy criteria, to selected areas of the Site where such caps will provide the same protectiveness as the ROD Remedy, assure permanent stability and performance, and can be applied without adversely affecting navigation, flood capacity, or habitat uses of the river. As more fully described in Section 5, the specific areas where caps could be placed either alone or in combination with dredging as part of the Optimized Remedy were determined based on the results of the comprehensive RD sampling and analysis program and the outcome of engineering evaluations that considered the specific characteristics of individual site areas;
- Maximize the implementability of the overall remedy, considering the constructability of different dredge and cap plans, transportation options, the availability of upland disposal facilities, and beneficial use opportunities; and
- Reduce the time frame for implementation and improve cost-effectiveness relative to the ROD Remedy.

As more specifically described in Section 5 of this BODR, the Optimized Remedy includes the following:

- **Site Mobilization and Preparation**. Staging areas similar to those described above for the ROD Remedy will be needed to support the remedial action. Staging areas will also be designed to optimize complimentary elements of the remedy. Preparation for remedial actions also includes landfill permitting and/or disposal agreements.
- **Sediment Removal**. In many areas of OUs 2 to 5, sediment removal will be performed in a manner equivalent to that described for the ROD Remedy (i.e., dredging to the 1 ppm RAL with a single hydraulic dredge). However, because of lower sediment removal volumes under the Optimized Remedy (relative to the ROD Remedy), in some situations different process equipment will be used to achieve overall project efficiencies, as discussed in further detail in this BODR. For example, sediments potentially subject to TSCA disposal requirements will be dredged hydraulically and processed using mechanical dewatering equipment (versus mechanical dredging and passive dewatering of these materials under the ROD Remedy), thus providing overall efficiencies that are different from the ROD Remedy (see discussion below). As with the ROD Remedy, removal will generally occur following a high-to-low concentration and upstream-to-downstream sequence to minimize the potential for recontamination. Sediment removal will be coordinated with USACE navigation channel maintenance and environmental dredging actions as appropriate.
- **Sediment Desanding**. As in the ROD Remedy, desanding of dredged sediments will occur at an upland processing facility, to the extent that beneficial uses of particular volumes of the separated sand have been established. Separated sands will be beneficially used in both on-site (e.g., partial fill of the staging area) and off-site applications as practicable. Based on the observed grain size distribution in the sediment of the planned dredge prism, approximately 225,000 cy of segregated sand is potentially available under the Optimized Remedy, all of which is targeted for potential beneficial use.
- **Sediment Dewatering and Disposal**. The lower dredging volume (compared with the ROD Remedy) makes mechanical dewatering at the upland staging facility feasible for all sediments dredged under the Optimized Remedy, including sediments requiring disposal at a TSCA landfill. Non-TSCA dewatered sediments will be transported by truck to a dedicated engineered landfill or other suitable disposal facility, consistent with Wisconsin Administrative Code NR 500 and other applicable regulations. Dewatered sediments requiring disposal at a TSCA landfill will be transported to an appropriate engineered landfill facility specifically permitted to handle this type of waste.
- **Water Treatment**. Treatment of water generated by the dredging, desanding, and dewatering operations, as well as all storm water collected from the upland staging facility, will be performed in a manner equivalent to that of the ROD Remedy.
- **In situ Caps and Covers**. In certain areas, where permanent stability and performance can be assured, engineered armored caps will be constructed consistent with the contingent remedy provisions of the RODs. Similar to the ROD Remedy, in situ capping of sediments exceeding the 1 ppm RAL may also be performed along shoreline areas or surrounding in-river and near-shore structures where RD engineering evaluations conclude that dredging would adversely affect the stability of the existing slopes. Sand covers will be placed as needed to address surficial post-dredge residuals (see below). Sand covers will also be placed over certain thin deposits of low concentration sediments in a manner designed to ensure protectiveness..
- **Post-Dredge Residual Management**. As in the ROD Remedy, management of dredge residuals will likely be required to meet the overall SWAC goals, and may include placement of a sand cover or engineered cap on or immediately adjacent to the dredged surface (as

appropriate for the individual location), redredging where the consistency of the settled materials are suitable for cost-effective dredging, or other adaptive management options informed by the results of post-dredge sampling and analysis data.

- .**Demobilization and Site Restoration**. Demobilization and site restoration will be performed in a manner equivalent to the ROD Remedy. Similar to the ROD Remedy, and as explained in Section 5, staging area improvements (e.g., wharf construction) will be retained.
- **Natural Recovery, Monitoring, Maintenance, and Institutional Controls**. Similar to the ROD Remedy, a long-term monitoring and institutional control plan will be developed as part of RD. Additional institutional controls, monitoring and maintenance will also occur to ensure the permanent effectiveness of caps. As with the ROD Remedy, land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of certain areas of the Site.

The Optimized Remedy design is described in more detail in Section 5 of this BODR. Both the ROD Remedy and Optimized Remedy have been carried forward as design options in this BODR.

1.7 Relationships to Other Programs

1.7.1 OU 1 Remedial Actions

In September 2003, WTM 1 Company (formerly Wisconsin Tissue Mills in Menasha) and P.H. Glatfelter Company (owner of the former Bergstrom Mill in Neenah) entered into a Consent Decree with USEPA and WDNR to expedite the cleanup of OU 1 (CH2M Hill 2004). As summarized in the Consent Decree, the selected remedy for OU 1 includes active remediation of the PCB-contaminated sediment (i.e., dredging, dewatering, and off-site disposal).

Cleanup of OU 1 began in 2004 within Little Lake Butte des Morts, which is a six-mile widening of the Fox River between the dams located in Menasha and Appleton, Wisconsin. GW Partners, LLC consisting of WTM 1 and P.H. Glatfelter, coordinated the effort under the oversight of the USEPA (Region 5) and WDNR.

The 2004 cleanup effort involved dredging PCB-contaminated sediment from the lake bottom with an eight-inch hydraulic cutterhead dredge, and transporting the slurried material via a HDPE pipeline into very large mesh bags (geotextile tubes) staged on a composite lined, gravel surfaced dewatering pad. These tubes were used to drain the water from the dredged lake bottom sediment. The resultant effluent was then treated at the on-site water treatment facility and returned to the lake. After the sediment had dried in the tubes, it was loaded into sealed dump trucks for transport to the Onyx Hickory Meadows Landfill, LLC in Chilton, Wisconsin.

The 2004 dredging efforts removed more than 17,000 cy of sediment containing PCBs from the lake; those sediments were disposed of in the Onyx landfill. Following review of data obtained from the first year effort, decisions were made on how to proceed in 2005. The 2005 remediation efforts

removed, processed and disposed of approximately 90,000 cy of impacted sediment in a similar manner as 2004, as described below.

In-water work resumed on Little Lake Butte des Morts (LLBM) in July 2005. The dredging initially began with one 8-inch-diameter hydraulic dredge operating 24-hours-per-day, 5-days-per-week. Following the initial start up period, the project began concurrently operating a second 8-inch dredge dredge. The first phase of the 2005 dredging season required a floating pipeline from the staging area to the southwest corner of the lake near Arrowhead Park (Sub-area A). Dredging proceeded in this area of the lake until early November 2005. At that time, both dredges were relocated to the western shore of the lake, south of Fritse Park in Sub-areas C and D2S. In mid-November 2005, a third 8-inch dredge was mobilized to the site to dredge PCB impacted sediments in Sub-area POG1 on the east side of the lake, north of the railroad trestle and west of the Menasha locks. Dredging ended for the season in all three of the OU 1 areas during the first week of December due to ice formation on LLBdM. Following removal and dewatering in geotextile tubes, the sediment is currently (i.e., as of February 2006) being disposed of in the Onyx Hickory Meadows landfill.

Removal of PCB-contaminated lake sediment in OU 1 is expected to take several years to complete, at an estimated cost of approximately $60 million.

1.7.2 Water Resources Development Act Authorities

A WRDA Feasibility Study was initiated by the USACE and WDNR to investigate and appraise the Federal interest and determine the extent of Federal participation in environmental dredging on the Lower Fox River and Green Bay, following the results of an earlier Section 905(b) (WRDA 86) Reconnaissance Study performed by the USACE. The WRDA study area encompasses the entire 39-mile segment of the Lower Fox River beginning at the mouth of Lake Winnebago, and includes all of Green Bay to a line from the northern tip of the Door Peninsula to the southern tip of the Garden Peninsula.

As described in more detail in the RODs and supporting documents prepared by the Response Agencies, multiple chemicals of concern have been identified in the Lower Fox River in addition to PCBs. Further, many other potentially responsible parties (PRPs) in addition to the Participating Companies have been identified by the Response Agencies with respect to historical PCB releases to the river. There are no existing agreements or orders for implementation of any cleanup actions under CERCLA in OUs 2 to 5. (A different set of PRPs has separately agreed to conduct the remedial design and implementation in OU 1, as summarized in Section 1.7.1.)

The RD Work Plan approved by the Response Agencies for OUs 2 to 5 concluded that many elements of a concurrent WRDA 90 Section 312 Feasibility Study could overlap with CERCLA remedial design requirements, and also recognized that there may be an opportunity for WDNR, as the local

WRDA sponsor, to supplement and/or leverage this effort with in-kind services as part of the local sponsor's Feasibility Study cost share. For example, the RD Work Plan envisioned separate WRDA evaluations of the active navigation channel of OU 4 downstream of the Fort Howard turning basin (denoted OU 4B), along with effective coordination between the various CERCLA and WRDA activities, to achieve an efficient integrated effort. A separate WRDA Scope of Work prepared by the WDNR and USACE provides additional details on the framework for the integrated effort.

WRDA authorities and associated funding are appropriate to the extent that portions of the sediment contamination are traceable to "orphan shares," associated, for instance, with discharges of PCBs, mercury, chlorinated pesticides, or other pollutants not traceable to the Participating Companies. In general, methodologies for determining equitable shares for USACE participation through WRDA 90 Section 312 include:

A. Identification of "orphan share" contaminants that could potentially contribute to cleanup requirements but for which specific sources and viable PRPs have not been identified in the CERCLA process; and

B. Determination of orphan share portions of the overall contaminant load in the Lower Fox Fiver for contaminants that have identified PRPs for some portion of the loading to the Lower Fox River (primarily PCBs).

Equitable share analysis using each of these methodologies is briefly outlined below.

A. **Orphan Share Contaminants**. The CERCLA process has not resulted in the identification of PRPs responsible for any chemical other than PCBs, and there are no current plans to do so. As such, the share of cleanup liability attributable to other chemical releases is an "orphan" share in the CERCLA context, and addressing such contamination through use of WRDA 90 Section 312 funds will not run afoul of USACE guidance concerning environmental dredging at CERCLA sites. The resulting WRDA scope of work may overlap with and/or complement work that could be performed with existing and/or potential future settlement funds in the CERCLA context. The overall program is expected to be superior to what could be accomplished with either a CERCLA remedial action or an environmental dredging project standing alone.

B. **Orphan Share Portions of PCB Loading**. The Participating Companies currently engaged in the RD process represent some portion, but not all, of the historic responsibility for PCB releases to the Lower Fox River. Addressing a portion of the PCB cleanup attributable to non-participating companies through WRDA environmental dredging authorities comports with USACE environmental dredging guidance requirements, as it represents an orphan share for which the Participating Companies are not responsible. This is also consistent with EPA's orphan share policy that allows for federal funding of identified orphan share liability (see EPA's Interim Guidance on Orphan Share Compensation for Settlors of Remedial Design/Remedial Action and Non-Time-Critical Removals, June 1996).

Other ways to differentiate the federal interests from PRP responsibility may also become apparent during the conduct of the WRDA Feasibility Study.

2. SITE CHARACTERISTICS

2.1 Sampling and Analysis Data

2.1.1 Pre-Design Data

In developing the RD Work Plan, data available as of early 2004 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 provisions of the ROD and alternative disposal sites, were performed to focus initial (2004) sampling and analysis and initial RD 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 focused on OU 2 (Deposit DD), OU 3 and OU 4 (in their entirety), and the portion of OU 5 immediately adjacent to the mouth of the Lower Fox River that was identified in the ROD).

2.1.2 2004 Sampling and Analysis Program

Based on a review of the available data as outlined above, a detailed RD SAP and QAPP were prepared (Shaw/Anchor 2004). The purpose of the 2004 Sampling and Analysis Program was to gather field and analytical data from OUs 2 to 5 as necessary to support RD. The OU 2 to 5 RD investigation generated sediment characterization data essential to the engineering design of the remedial action. The primary activities associated with the OU 2 to 5 RD investigation included baseline surveying (by WDNR); delineation of the 1 ppm RAL, both horizontally and vertically; detailed hydrodynamic investigations and analysis; and physical characterization of OU 2 to 5 sediments as needed for design of the following remediation activities: removal (dredging), contingent capping, sediment handling, sediment dewatering, sediment and/or wastewater treatment as appropriate, and sediment transport, disposal, and/or beneficial use.

2.1.2.1 Summary of RD Sampling

The sampling associated with the RD activities involved collecting a sufficient number of high-quality samples to define the 1 ppm PCB remediation prism for future remedial activities associated with the sediment in OU 2 Deposit DD, OU 3, OU 4, and OU 5 adjacent to the Lower Fox River mouth. Sampling also included physical (geotechnical) characterization and determination of engineering properties for design purposes. In addition to sediment chemical and physical characterization, chemical mobility and treatability testing samples were also collected as part of the

RD sampling. Data collection methods are described in detail in the agency-approved SAP and QAPP and are not repeated herein. The 2004 sampling locations are depicted in Figure 2-1, and included collection of the following:

- 1,154 Vibracore and surface sediment (0-10 cm) sampling locations;
- Approximately 130 in situ vane shear at selected locations;
- 650 sediment samples collected and analyzed for selected geotechnical testing;
- 8,106 sediment samples collected and analyzed for selected physical and chemical parameters; and
- 8 samples from different regions of the river composited for detailed chemical mobility and desanding tests.

The coring grid provided a minimum coverage of 1 core per 6.2 acres in less critical areas, and 1 core per 1.6 acres in more critical areas, including areas with sediments potentially subject to TSCA disposal requirements. Targeted PCB core profiles were obtained on 0.5-foot vertical intervals (prior to compaction correction) to accurately determine the "neatline" depth of contamination, particularly relative to the 1 ppm RAL, and the delineation of deposits potentially subject to TSCA disposal requirements. Data collected during the 2004 Sampling and Analysis Program have been separately submitted to the Response Agencies; a brief overview of the program is provided below.

2.1.2.2 Testing Methods (Chemical and Geotechnical)

PCBs were analyzed using the Fox River Method to ensure comparability with existing and historical data. The Fox River method is a series of four methods performed in the following sequence: particle size reduction, extraction (Soxtherm), extract cleanup, and gas chromatography analysis.

Samples collected specifically for geotechnical analyses were tested for moisture content, specific gravity, grain size distribution, Atterberg limits, stress strain properties, laboratory vane shear test (VST), consolidation, and organic content at the frequency stated in the agency-approved SAP and QAPP (Shaw/Anchor 2004) and are not repeated herein. In addition to the ex situ laboratory testing listed above, in situ testing included Standard Penetration Test (SPT) borings, cone penetrometer testing (CPT), and shear strength measurements using the in situ VST.

2.1.2.3 Treatability Testing (Chemical Mobility & Desanding)

A suite of chemical mobility and desanding tests were conducted using bulk sediment samples composited from three areas in OU 3, four areas in OU 4, and one area in OU 5, as detailed in Shaw/Anchor (2004). Each area was represented by sediment composited from five cores over the depth of contamination. The areas were selected to provide a range of PCB concentrations that will likely be encountered in the prospective dredging prism, ranging from high and relatively "worst-case" concentrations, to average and lower concentrations.

The various contaminant mobility tests performed on the 8 composite samples are briefly outlined below:

- Dredging Elutriate Tests (DRETs) were performed to simulate the release of dissolved and particulate constituents into the receiving water at the point of dredging, and to evaluate the potential for short-term water quality effects during construction. The test results are used in conjunction with dredge plume models developed by the USACE (e.g., DREDGE), to simulate the dissipation and attenuation of the dredge plume through the mixing zone.
- Modified Elutriate Tests (METs) were performed to characterize water quality associated with supernatant water (dredging effluent) released from an upland or nearshore sediment handling or disposal facility. These test results are used to help determine appropriate options for disposition of the effluent water.
- Column Settling Tests (CSTs) were performed to characterize the time-dependent settling and clarification of the supernatant water (dredging effluent) released from an upland or nearshore sediment dewatering and/or disposal facility. These test results are used to help determine appropriate options for disposition of the effluent water, retention requirements for sedimentation, and to support the design of the dewatering and/or disposal facility.
- Pancake Column Leaching Tests (PCLTs) were performed to assess potential chemical leaching from contaminated sediments, either dredged and placed in a disposal facility, or in situ as part of the Optimized Remedy. These tests, in conjunction with contaminant transport modeling, support predictions of long-term water quality effects that may be associated with contaminant migration at a disposal site or through a cap to the receiving water of the Lower Fox River.
- Bench-Scale Sand Separation Treatability Testing was performed to assess potential desanding options for the dredged slurry, either to separate a non-contaminated sand fraction or to separate the sand to reduce wear on the pipeline transporting the dredged slurry. The desanding methodology tested utilized a combination of physical separation processes to separate the PCB contaminated fine particles from the separated sand particles. A combination of physical separation technologies, particle size classification and attrition scrubbing were incorporated to separate the PCB-impacted fine fractions from the separated sands.

2.1.2.4 Data Validation

A data validation process was conducted to assess the reliability and usability of sampling and analysis data collected during the 2004 RD evaluation. There were two areas of review: laboratory performance evaluation, and the effect of matrix and sampling interference. Evaluation of laboratory performance was a check for compliance with the method requirements and is a straightforward examination: the laboratory either did or did not analyze the samples within the quality control (QC) limits of the analytical method and according to protocol requirements. The assessment of potential matrix and sampling effects consists of a QC evaluation of the analytical results; the results of testing blank, duplicate, and matrix spike (MS) samples; and assessing how, if at all, this could affect the usability of the data. The 2004 data validation reports were provided to the Response Agencies under

separate cover as part of the RD Data Report (Shaw/Anchor 2006a). All data collected during this period were deemed acceptable for use in RD as qualified.

2.1.3 2005 Sampling and Analysis Program

Following completion of the 2004 Sampling and Analysis Program, it was determined that additional sample locations were needed in areas where increased definition of PCB distribution will help define the dredge prism more accurately. In addition, it was determined that there was a need for additional geotechnical information to further support evaluation of the contingent remedy. Subsequently, a detailed RD SAP and QAPP addendum was prepared (Shaw/Anchor 2005). The 2005 Sampling and Analysis Program objectives were as follows:

A. Further delineation of PCB distributions greater than 50 ppm along prospective TSCA boundaries in OU 4

B. Further delineation of PCB distributions greater than 1 ppm within OUs 3 and 4

C. Determination of PCB distributions within the upstream "off-limit" boundaries of the De Pere (OU 3) and Little Rapids (OU 2) Dams

D. Geotechnical analysis within the prospective Cat Island habitat restoration and beneficial use area

The 2005 sampling locations are depicted in Figure 2-1, and included collection of the following:

- 148 Vibracore locations;
- Approximately 130 in situ vane shear at selected locations;
- 1,600 sediment samples collected and analyzed for selected physical and chemical parameters; and
- Focused geotechnical sampling and analysis.

2.1.3.1 Testing Methods (Chemical and Geotechnical)

Testing methods used in 2005 were identical to those used in 2004 (see Section 2.1.2.2).

2.1.3.2 Data Validation

A data validation process was conducted to assess the reliability and usability of sampling and analysis data collected during the 2005 RD evaluation. The validation process was equivalent to that used for the 2004 program, as summarized in Section 2.1.2.4. The 2005 data validation reports were provided to the Response Agencies in electronic format. The RD Data Report (Shaw/Anchor 2006a) presents the data validation report for the 2005 dataset. All data collected during this period were deemed acceptable for use in RD as qualified.

2.2 Summary of Physical Site Characteristics

The remedial designs developed herein for OUs 2 to 5 were based on consideration of a number of key site features, including physical and chemical characteristics. Physical characteristics relevant to design of the sediment remedial action are summarized below. Chemical characteristics are summarized in Sections 2.3 and 2.4.

2.2.1 Site Units and Uses

A summary of site units is provided in Section 1.2. Table 2-1 provides a general description of the land use within each operable unit as well as a breakdown of the percentage of the various land uses within 0.25 miles of the river. Additional detail of the land use along the Fox River is provided below.

Table 2-1a. 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%
Woodland	16.20%
Parks	9.30%
Agriculture	5.80%
Public	4.30%
Wetlands	3.40%
Vacant	6.05
	100.00%

Source: FS (Retec 2002)

Table 2-1b. 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

OU 3. The river banks along much of OU 3 are occupied primarily by residential properties and by St. Norbert College at the northern end of the reach, immediately upstream of the De Pere Dam. A public access boat launch is also located at the northern end of the reach; opposite St. Norbert College. Most of OU 3 is used by recreational and fishing boats and personal water craft, primarily between March and November (WDNR 2005).

OU 4. The area around OU 4 is highly urbanized, including the City of Green Bay. A significant portion of the shoreline in OU 4 is lined with vertical bulkheads to support commercial and industrial activities on the adjacent uplands. Several marina facilities are located along the banks of OU 4. Water use includes recreational (boating and fishing), commercial (tour boats), and industrial navigation (shipping within the Federal navigation channel). Most of OU 4 is used by recreational and fishing boats, primarily between March and November (WDNR 2005).

2.2.2 Site Constraints

2.2.2.1 Locks and Dams

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 Neenah and Menasha Dams control discharge from Lake Winnebago to Little Lake Butte des Morts (OU 1).

There are two dams within the OU 2 to 5 project area including the De Pere Dam at RM 7.1 separating OU 4 and OU 3 and the Little Rapids Dam at RM 13.1 separating OU 3 and OU 2. There is a lock system at both of these dams.

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).

The dams are under the authority and ownership of the USACE, with local control and maintenance residing in the DePere (WI) area office, and decision making authority residing in the Detroit district office. It is the USACE's intent (and standard operating procedure) that the dams be maintained at their current operational status, with necessary repairs and maintenance performed to insure their continued efficiency in controlling river flows. Currently, the federal government is in the process of transferring authority and ownership of the locks to the State of Wisconsin. There are no current plans to remove any of the locks or dams in the OU 2 to 5 project area, or any of the other 15 locks or 11 dams.

Section 5.7 of this BODR (*Monitoring, Maintenance, and Institutional Controls for Capping*) includes a discussion of institutional controls to ensure the continued protectiveness of caps constructed consistent with the contingent remedy provisions of the RODs. An Institutional Control Plan will be prepared as part of the 60 Percent Design that will more fully describe institutional controls required, building on prior agreements that have been implemented at other similar sediment Superfund capping sites.

2.2.2.2 Water Depth and Bathymetry

A bathymetry survey to support the RD was performed by Retec during the summer of 2004. The 2004 bathymetric survey included the use of a multiple transducer, single-beam sweep system that collected data over a 35-foot swath, ultimately resulting in a 3-foot by 5-foot data point grid. This data grid has been used to generate all of the bathymetric maps used to support this BODR.

The following sections provide a brief description of the bathymetric and water depth conditions in each OU.

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, covering approximately 35 acres (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 (north to south) between the Little Rapids and De Pere Dams covering approximately 950 acres. 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 depth along the center of the river is generally 7 to 9 feet throughout most of the southern half of the reach, deepening towards the north with a max of approximately 18 feet above the De Pere Dam. Relatively shallow (2 to 5 feet of water) shoaling areas are located along both banks in most 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 2002).

OU 4. OU 4 includes the 6-mile-long (north to south) reach between the De Pere Dam and Green Bay covering a total area of approximately 1,275 acres. 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 in the upper reaches of OU 4 (denoted OU 4A), much of this width is occupied by shallow benches along both banks with water depths of 1 to 5 feet. The Fort Howard turning basin, the upstream end of which marks the boundary between OU 4A and OU 4B, is routinely dredged by the USACE and Brown County to maintain the authorized turning basin depth of 20 feet (USACE 2003).

Downstream of the Fort Howard turning basin, approximately 150 feet of the 300-foot-wide federally authorized channel is routinely dredged to maintain the authorized navigation depth of 24 feet. 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 an engineered channel morphology with steeper side slopes.

OU 5. OU 5 begins at the river mouth, and includes the entire bay of Green Bay. The primary focus of this BODR is a relatively small deposit, located immediately offshore of the Fox River mouth, which is defined as a 1,500-foot radial distance from the mouth of the river (covering approximately 75 acres). At the mouth of the Fox River at Green Bay, the water depth is relatively shallow (less than 10 feet) except within the limits of the federal navigation channel where the USACE maintains the authorized depth of 24 feet.

The low-water pool elevations maintained in OUs 2 to 5 are summarized in Table 2-3.

Table 2-3. Low Water Pool Elevations in OUs 2 to 5

Pool	Operable Unit	River Mile	Low Water 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

Note: Low Water Pool elevations from NOAA (2002)

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 and Huron. Section 5 of this BODR provides additional discussions related to the water elevation in each OU as they relate to the Optimized Remedy evaluations.

2.2.2.3 Federal Navigation Channels & Reauthorization

The currently authorized federal navigation channel in OU 5 consists of an outer channel in Green Bay in OU 5, extending from the river mouth to Grassy Island. This outer channel is approximately 300 to 500 feet wide and authorized to 26 feet deep (USACE 2003). From Grassy Island to the mouth of the Lower Fox River, the navigation channel is authorized to a depth of 24 feet (USACE 2003).

From the mouth of the Lower Fox River at Green Bay, the federal navigation channel extends 7.1 miles through OU 4 to the De Pere Dam. However, consistent with prior requests by the local sponsor (Brown County), only portions of the federally-authorized channel are currently maintained

by dredging, performed by the USACE. As discussed above, this actively maintained portion is located between the mouth of the river and the Fort Howard turning basin (denoted OU 4B), including only a portion of the federally authorized channel width in this area.

The majority of the OU 4B navigation channel is authorized to a depth of 24 feet, with the exception of a very short section (less than 200 feet) north of the Fort Howard turning basin (authorized depth of 22 feet). In addition, the Fort Howard turning basin (RM 3.4), which extends 1,700 feet upstream of the Chicago and Northwestern Railway Bridge, is authorized to a depth of 20 feet (USACE 2003).

Upstream of the Fort Howard turning basin (extending to the De Pere Dam), the federally authorized channel in OU 4A was previously established at 150 feet wide and 18 feet deep. This portion of the navigation channel has been in "caretaker" status for years and is not actively maintained. Recently, local agencies approved the reauthorization of the OU 4A navigation channel to 75 feet wide and 6 feet deep. The channel modification was incorporated into the 2005 WRDA bill and approved by the House in July 2005[1]. Senate approval is pending.

A downstream turning basin at the mouth of the East River (RM 1.4) has been established at a depth of 24 feet. All water depths within the OU 4 federal navigation channels have been established by the USACE relative to the National Oceanographic and Atmospheric Administration (NOAA) low water surface elevation of 577.5 feet International Great Lakes Datum 1985 (IGLD 1985, without hydraulic correction; see Table 2-3 above and Section 5 below).

2.2.2.4 Infrastructure, Utilities, and Obstructions

Numerous forms of infrastructure and obstructions lie within or cross the Lower Fox River (Figure 2-2). These features may provide constraints or limitations on construction operations during remediation. They include:

- Road and railway bridges;
- Locks and dams (as discussed above)
- Submerged pipelines;
- Submerged cables;
- Overhead cables;
- Outfalls;
- Other submerged structures (ruins, cribs, etc.);

[1] The OU 4A channel reauthorization was incorporated into the House-approved 2005 WRDA bill as follows: Sec. 3103. "Green Bay Harbor Project, Green Bay, Wisconsin. That portion of the inner harbor of the Federal navigation channel of the Green Bay Harbor Project, authorized by The Act of June 23, 1886, beginning at Station 190+00 to Station 378+00 is authorized to a width of 75 feet and a depth of 6 feet effective with the enactment of this Act."

- Rocks and debris;
- Submerged or exposed pilings and dolphins;
- Seawalls, bulkheads, and over-steepened slopes; and
- Active or inactive piers or wharfs.

As part of initial RD work for this BODR, desktop and field surveys were completed to identify and locate all known utility crossings within the river. The desktop search included a review of NOAA charts for the Lower Fox River (NOAA 2002) and GIS files provided by WDNR. Representatives for the owners of each utility were contacted as necessary to provide or confirm utility locations.

OU 2. Infrastructure and obstructions in those portions of OU 2 addressed in this BODR (i.e., Deposit DD) include the following:

- Little Rapids Dam (RM 13.1); and
- Little Kaukauna Locks (RM 13.1) - Depth over sill of 6 feet, width of 35 feet, and length of 144 feet (NOAA 2002).

OU 3. Obstructions within OU 3 include the following:

- Little Rapids Dam (RM 13.1) (this dam forms the border between OU 2 and OU 3)
- Three sets of overhead cables north of Little Rapids Dam – minimum clearance of 77 feet.
- Submerged pipelines;
- Submerged cables south of De Pere Dam; and
- Ruins at the southern and northern ends of the OU.

OU 4. Infrastructure within OU 4 includes the following road and rail bridges with horizontal and vertical clearance as indicated:

- 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;
- Submerged pipelines and cables frequent through northern end of OU 4 and;
- 15 outfalls, one at the De Pere Sewage Treatment Facility and the remainder north of the Fort Howard turning basin;
- Potentially sunken ships or barges as indicated on NOAA chart, typically near the bridges;
- Archeological sites; and
- Seawalls, bulkheads, and over-steepened shoreline slopes adjacent to the Fort Howard turning basin, and in several other areas of OU 4. Note that in order to maintain stable side slopes and shoreline infrastructure adjacent to the SMU 56/57 demonstration project, dredge cuts in that area were designed at 5 horizontal to 1 vertical (5H:1V; Foth & Van Dyke 2001). As discussed in more detail below, geotechnical data collected during the 2004 and 2005 RD investigations suggest that similar side slopes and setback requirements may be required in other shoreline areas of OU 3 and 4.

More detailed evaluation of infrastructure, utilities, and obstructions in the project area is planned for spring 2006, and such data will be incorporated into the 30 Percent and/or 60 Percent Design submittals.

2.2.3 Regional Geologic Conditions

The Deposit N demonstration project highlighted the importance of regional geologic conditions, such as the presence of near-surface fractured bedrock, as a primary factor to be considered in dredge plan design (Foth & Van Dyke 2000). The entire 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 may 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).

Prior to the 2004 and 2005 RD sampling, the presence and distribution of near-surface fractured bedrock was not well characterized within the Lower Fox River, particularly within OU 4. The RD field program described above identified regions of the river where fractured bedrock appears to immediately underlie contaminated sediment deposits, and thus will need to be addressed as part of RD.

2.2.4 Regional Hydraulic Conditions

Regional hydraulic conditions may also be important to RD, particularly at those locations within the river where caps may need to be installed to protect shoreline slope stability, or where protective contingent cap designs may be implemented more broadly as part of the Optimized Remedy. Regional hydrogeologic conditions are briefly reviewed below.

2.2.4.1 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 2-3. As discussed in the Lower Fox River Remedial Investigation Report (RI; Retec 2002c), groundwater may discharge from the Upper Aquifer to the Lower Fox River during periods of low or base flow. However, discharge to the river is limited due to the following factors:

- Relatively impermeable surficial deposits of the river bed;
- Relatively impermeable fractured Ordovician limestone and dolomite bedrock outcrops in the river bed;
- Moderate to low head conditions between the Lower Fox River and the Upper Aquifer;
- High surface runoff after storm events, reducing recharge to the Upper Aquifer; and
- Increased pumping rates for municipal and industrial use, and resulting aquifer drawdown.

In a water supply modeling study (USGS 1998), the volume of water in the Lower Fox River was measured at several points along the river from Little Lake Butte de Morts to the river mouth at Green Bay in order to estimate the contribution of groundwater to the river. For rivers with groundwater contributions, the expectation is that flow volume will increase downstream even after taking into account tributaries and other sources. In the case of the Lower Fox River, there was only a relatively

minor unaccounted change in volume over the 39 miles, supporting the case of limited groundwater discharge. For the same study, an inspection of a dolomite quarry in Kaukauna, approximately 100 feet from the Lower Fox River, revealed limited groundwater discharge into the quarry from several hundred feet of dolomite, further supporting the case of limited ground water movement through this formation and therefore no source to discharge to the river (Conlin 2002, Krohelski 2002).

Although the majority of the Upper Aquifer is comprised of relatively low permeability material, lenses of sand and gravel could potentially produce locally significant discharges to the Lower Fox River where such lenses intersect the river bed. However, detailed sampling and analysis of the river during the 2004 and 2005 RD investigations did not reveal any such lenses. Groundwater flow is discussed in more detail in Section 5.

2.2.4.2 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 1-1). 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 above.

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 parts of the river bed. Groundwater discharge to the river is therefore limited.

Rainfall-Runoff. In a typical year, Green Bay receives 28.8 inches of total precipitation. 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 (Table 2-4; Retec 2002c).

Lower Fox River Flows. The U.S. Geological Society (USGS) has monitored stream flow in the Lower Fox River at several different gaging stations within the watershed. By far the longest stream gaging record is at the Rapide Croche Dam in Wrightstown in the lower reach of OU 2 (#04084500). Flow rates at Wrightstown have been recorded continuously since 1917 providing a long term data set for determination of flow recurrence intervals (http://waterdata.usgs.gov/wi/nwis/rt; WDNR 2000). Summary statistics of Lower Fox River discharge data for the Rapide Croche Dam station are summarized in Table 2-4.

Flow rates during a typical year vary from 30 to 280 cubic meters per second (m^3/s; 1,060 to 9,900 cubic feet per second [cfs]). The highest discharge typically occurs during the spring months of

March through June, when the river is recharged by snowmelt and spring rains. The highest flow rate recorded on the river in the past 80 years is approximately 650 m^3/s (23,000 cfs) and corresponds to a 50 year recurrence interval, as summarized in Table 2-5.

In addition to the gage at the Rapide Croche Dam, the USGS has operated an acoustic velocimeter (AVM) in OU 4, about 0.8 miles upstream from the river mouth, since 1989 (Table 2-4). 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 gages (drainage area increases by only 5 percent between the two gaging stations). There is little additional surface water recharge, and as discussed above also little gain or loss due to groundwater within this lower reach of the river. Seiche effects evident at the mouth gage are discussed below.

Table 2-4. 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

Table 2-5. Summary of Lower Fox River Flow Rates at Rapide Croche Dam

Recurrence Interval (years)	Flow (m^3/s)	Flow (cfs)
2	360	12,700
5	481	17,000
10	544	19,200
25	612	21,600
50	651	23,000
100	685	24,200

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 armored cap elements of the ROD and Optimized Remedies (Palermo et al. 1998a & 1998b, Johnson Co. 2001). The USGS and Sea Engineering Inc. (SEI 2004 & 2005) recently completed a study of the hydrodynamics in OUs 3 and 4 under various flow conditions. The study included the collection of vertical velocity profiles by the USGS at 30 locations in OU 4 during four events spanning a range from low (100 m^3/s [3,500 ft^3/s]; seiche dominated) to high (400-450 m^3/s [14,100 to 15,900 cfs]; flood dominated) river flow conditions. Vertical velocity profiles were also measured by the USGS at 33 locations in OU 3 during a single moderate flow event (250 m^3/s [8,800 cfs]). SEI used the field data collected by USGS to develop and calibrate a 2-dimensional hydrodynamic model to predict bottom shear stresses in both OU 3 and OU 4. The SEI reports for OUs 3 and 4 are provided in Appendix D.

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 gaging records and river cross-section data (WDNR 1995). The average annual river velocity in OU 3 is approximately 0.40 feet per second (fps), and the average river velocity in OU 4 is roughly 0.26 fps. These average velocities are within the range of values where silt- and sand-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. As discussed in Section 5, more detailed evaluations of river velocity under the Optimized Remedy were performed for this BODR using the SEI models.

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. Historical stage records for the Fox River indicate that seiches typically occur twice daily with a return period of approximately 11 hours. 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, Gailani et al. 1991).

Variations in flow caused by seiche effects are largest near the mouth of the Lower Fox River at the OU 4 / OU 5 boundary, and progressively decrease for approximately 7 miles upstream to the De Pere Dam. Reversing currents associated with the seiche effects has resulted in instantaneous peak discharges at the river mouth as high as 957 m^3/sec (33,800 cfs). As discussed in Section 5, worst-case seiche effects are considered in the cap armor design for capping elements of the ROD Remedy (e.g., certain shoreline areas), and the Optimized Remedy.

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 the December 2003 is 578.94 feet IGLD 1985, as shown on the hydrograph on Figure 2-4. This hydrograph also indicates that the Lake Michigan-Huron basin experiences extended periods of extremely low water (below the NOAA low water datum of 577.5 feet IGLD 85) approximately every 30 years. The historical low and high lake water levels since 1918 are 576.05 feet (March 1964) and 582.35 feet (October 1986), respectively (USACE 2004). Recent lake levels have been below LTA elevations, due to lower than average snowmelt runoff and several consecutive warm winters.

Figure 2-5 presents the hydrograph of water elevations measured at the mouth of the Fox River in Green Bay (NOAA Station 9087079) for the period 1979 through 2005. Short-term variability in water levels is evident in the Figure 2-5 plot. Consideration of both short- and long-term temporal changes in water levels is an important element of cap design, and further discussion of seasonal probabilities of water and ice elevations in the river is provided in Section 5 of this BODR.

2.2.5 Geotechnical Conditions

The geotechnical properties used for this design were evaluated during two separate RD field investigations conducted by the Shaw/Anchor team (Shaw/Anchor 2004 and 2005). Numerous other studies were conducted prior to the Shaw/Anchor investigations (since 1989), but the results of these investigations were used only to help guide the Shaw/Anchor sampling since historical data contain limitations including (1) lack of subsurface (below 10 cm) samples; (2) cores were collected by different investigators, using different field methods, and years apart in time; and (3) cores from different studies were likely subjected to different degrees of sampling-induced compaction. Therefore, the sampling scheme described in the SAP (Shaw/Anchor 2004 and 2005) was intended to provide a stand-alone data set to support RD.

The following sections present a summary of the data collected during the Shaw/Anchor RD sampling investigations. The data presented in this section is intended to provide a representative summary of OUs 2-5 as a whole and not specifically those sediments targeted for dredging. Sections 3 and 5 discuss the geotechnical properties of those sediments targeted for dredging under the ROD and Optimized Remedies, respectively. All geotechnical data is presented in the RD Data Report (Shaw/Anchor 2006a).

2.2.5.1 Grain Size

Grain size data were collected throughout OUs 2 to 5 of the Lower Fox River and Green Bay, including the Cat Island area of OU 5. In total, approximately 350 grain distribution tests (ASTM D-422) were performed on samples collected from between 0 and 9 feet deep (below the mudline).

In general, the sediments in OUs 2 to 5 of the Lower Fox River are comprised mainly of sand- and silt-sized particles, which account for approximately 75 to 80 percent by weight of the sediment matrix (Table 2-6). The remaining portion of the sediment matrix is comprised mainly of clay (approximately 20 percent) with a trace to slight amount (less than 5 percent) of gravel observed in some samples. These percentages (sand and silt vs. clay) are generally consistent between OUs, when reach-wide averages are compared. However, localized variability is apparent in most of the available datasets signifying that the river is a complex system with depositional and erosional areas. Maps depicting the spatial distribution of percent fines in surficial sediments (0 to 3 feet below mudline) in OU 2/3 and OU 4/5 are presented in Figures 2-6 and 2-7, respectively. Corresponding figures for subsurface sediments (greater than 3 feet below mudline) are presented in Figures 2-8 and 2-9.

Table 2-6. Summary of Grain Size Distribution Data

Operable Unit	No. of Samples	Sand/Gravel (%)	Silt/Clay (%)
OU 2 (Deposit DD Only)	3	23	77
OU3 (Little Rapids to De Pere)	108	45	55
OU 4 (De Pere to Green Bay.)	173	50	50
OU 5 (Green Bay)	9	55	45

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Values reported are numerical averages of available data. The full data set is available in the RD Data Report (Shaw/Anchor 2006a). Method used: ASTM D-422.

2.2.5.2 Atterberg Limits

Atterberg Limit (ASTM D-4318) tests were performed on approximately 380 samples collected during the Shaw/Anchor RD investigations within OUs 2 to 5. The data indicate high liquid and plastic limits, with liquid limits in most samples near or greater than 100 percent (Table 2-7). Average measured plastic limits range from approximately 36 to 43 percent.

Table 2-7. Summary of Atterberg Limit Data

Operable Unit	No. of Samples	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
OU 2 (Deposit DD Only)	3	187	43	145
OU3 (Little Rapids to De Pere)	130	141	40	101
OU 4 (De Pere to Green Bay.)	241	121	36	85
OU 5 (Green Bay)	9	113	37	76

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Values reported are numerical averages of available data. The full data set is available in the RD Data Report (Shaw/Anchor 2006a). Method used: ASTM D-4318.

Many of the samples within the Lower Fox River were classified as organic clay/organic silt (OH) or clayey sand (SC) and silty sand (SM) as defined by the United Soil Classification System (USCS).

2.2.5.3 Moisture Content and Percent Solids

Moisture content (ASTM D-2216) was measured on every sample collected during the Shaw/Anchor RD investigations. However, samples collected were compacted relative to in situ conditions as a result of the vibratory coring process. As described in the RD Work Plan (Shaw/Anchor 2004a), each of the measured moisture content values was compaction corrected, and the results presented in Appendix A. Percent solids, defined as the ratio of the weight of solids to the total weight of the sample (ranging between 0 and 100 percent), was calculated from the compaction corrected measured moisture content data. As indicated in Table 2-8, the average moisture content is greatest in OU 2 and decreases towards Green Bay. It should be noted that the project area in OU 2 is limited to Deposit DD immediately upstream of the Little Rapids Dam where fine-grained, high moisture content sediments typically accumulate. Maps depicting the spatial distribution of percent solids in surficial sediments (0 to 3 feet below mudline) in OU 2/3 and OU 4/5 are presented in Figures 2-10 and 2-11, respectively. Corresponding figures for subsurface sediments (greater than 3 feet below mudline) are presented in Figures 2-12 and 2-13.

Table 2-8. Summary of Moisture Content and Percent Solids Data

Operable Unit	No. of Samples	Moisture Content (%)	Percent Solids (%)
OU 2 (Deposit DD Only)	3	354	27
OU3 (Little Rapids to De Pere)	189	158	46
OU 4 (De Pere to Green Bay.)	389	137	50
OU 5 (Green Bay)	15	96	57

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Values reported are numerical averages of available compaction corrected data. The full data set is available in the RD Data Report (Shaw/Anchor 2006a). Method used: ASTM D-2216.

2.2.5.4 Density

Dry and wet bulk density measurements were calculated using the measured values for moisture content (compaction corrected as described above) and specific gravity as presented in Table 2-9. The average density in the OU 2 samples was measured as significantly less than the river-wide average. This may be due in part to the selection of the sampling locations in OU 2, which were focused on “deposits” and may not accurately reflect the properties of the entire OU.

Table 2-9. Summary of Calculated Density Data

Operable Unit	No. of Samples	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)
OU 2 (Deposit DD Only)	3	20	74
OU3 (Little Rapids to De Pere)	189	44	88
OU 4 (De Pere to Green Bay.)	389	48	91
OU 5 (Green Bay)	15	58	97

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Values reported are numerical averages of available data. The full data set is available in the RD Data Report (Shaw/Anchor 2006a).

2.2.5.5 Specific Gravity

Specific gravity (ASTM 854) measurements were collected during the RD investigations on approximately 45 samples. Given the generally consist geologic layering within the river, specific gravity does not vary significantly within the project area. Therefore, the sampling density (and hence, the total number of measurements collected) is significantly less than for other geotechnical properties. The results of the specific gravity tests are presented in Table 2-10.

Table 2-10. Summary of Specific Gravity Data

Operable Unit	No. of Samples	Specific Gravity
OU 2 (Deposit DD Only)	2	2.43
OU3 (Little Rapids to De Pere)	11	2.43
OU 4 (De Pere to Green Bay.)	28	2.42
OU 5 (Green Bay)	4	2.50

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Values reported are averages of available data. The full data set is available in the RD Data Report (Shaw/Anchor 2006a). Method used: ASTM D-854.

2.2.5.6 Strength

Sediment strength data collected during the RD sampling investigations consisted of undrained shear strength from in situ vane shear testing (VST), laboratory Torvane VST, unconsolidated undrained (UU) triaxial tests, and consolidated undrained (CU) triaxial tests.

During the 2004 and 2005 RD sampling of OUs 3 and 4, the undrained shear strength was measured at more than 160 test locations within OUs 3 and 4 at one-, two-, and three-foot depths using a field vane shear device. In the upper one-foot-interval, 105 tests within OU 3 and OU 4 were completed, and the measured shear strength ranged from approximately 15 to nearly 109 pounds per square foot [psf] (10th and 90th percentile values, respectively) with an average of approximately 50 psf. The

range of measured shear strengths was higher in the next two depth intervals at 2 and 3 feet below the sediment surface (average of 82 psf and 102 psf, respectively).

Results of the UU triaxial tests (ASTM D-2850) conducted as part of the Shaw/Anchor RD investigations indicate wide variability within OUs 3 and 4. Apparent cohesion measured in these UU tests ranged between 80 and 740 psf for samples collected from 2 to 6 feet deep. Results of the CU triaxial tests (ASTM D4767) on deeper samples (17 to 41 feet deep) of native soils showed less variability with measured cohesion ranging from 110 to 220 psf with internal friction angles ranging from between 25 and 35 degrees. However, it should be noted that only three CU triaxial tests were conducted as compared to six UU tests. The results of the triaxial tests of the native soils will be used in slope stability evaluations during later stages of design.

2.2.5.7 Consolidation Characteristics

Consolidation testing was performed as part of the Shaw/Anchor RD activities in OUs 3 and 4. Tests were performed using both the standard incremental load test (ASTM D-2435) and the seepage-induced consolidation testing (SICT) procedure developed by Liu and Znidarcic (1991). The SICT is a specialized methodology for consolidation testing of very soft soils and soil slurries, the output of which is a set of five parameters that define the relationship between void ratio and stress and between permeability and stress for the sample.

Four 5-point composite samples, representative of the potential OU 3 and OU 4 dredge prisms, were tested using the SICT method (Shaw/Anchor 2004). In addition, 17 discrete samples within OUs 3 and 4 were tested with the SICT methodology. The results of these SICT determinations are summarized in Table 2-11A. In addition, the results of the standard incremental load consolidation tests are presented in Table 2-11B, which include one test in native soils (4038-03; 17.5-19.5 ft).

2.2.5.8 Permeability

The seepage-induced consolidation test discussed above provides a relationship between permeability and void ratio. The permeability of samples prepared for SICT determinations ranged between 2.3 x 10^{-9} cm/sec and 1.3 x 10^{-7} cm/sec, with an average of 2.8 x 10^{-8} cm/sec. These samples were prepared at a percent solids slightly less than in situ conditions in order to ensure that the range of void ratios measured in the laboratory included the in situ conditions.

In addition to the SICT determinations, several permeability tests were conducted as part of the RD investigations using the ASTM methodology (ASTM D-5084) on samples collected from geotechnical borings advanced in OUs 3 and 4. These measurements ranged from between 2.4 x 10^{-8} and 1.8 x 10^{-7} cm/sec, with an average of 9.2 x 10^{-8} cm/sec. No significant differences in

permeability were observed between OUs 3 and 4. These data corroborate the conceptual site model of relatively impermeable surficial deposits of the river bed, as discussed above.

Table 2-11B. Summary of Consolidation Test Results by Incremental Load Method

Location	Sample Depth		Preconsol. Pressure, P_c	Compression Index	Recompression Index
	Top (ft)	Bottom (ft)	(tsf)	C_c	C_{cr}
3021-01	1	3	0.45	1.32	0.12
4038-03	5	7	0.175	0.68	0.13
4038-03	17.5	19.5	0.225	0.635	0.080

Note: All samples collected as part of Shaw/Anchor RD investigations (Shaw/Anchor 2004 and 2005). Method used: ASTM D-2435.

2.2.6 Standard Penetration Tests

As part of the OUs 2 to 5 RD sampling activities (Shaw/Anchor 2004), 12 geotechnical borings were advanced in OUs 3 and 4 with SPT blow counts measured at regular depth intervals. Disturbed split-spoon samples were collected at the location of all blow count measurements. Moisture content analyses were performed on all split-spoon samples collected. In addition, thin-walled, undisturbed Shelby tube samples were collected for advanced testing (unconsolidated undrained [UU] and consolidated undrained [CU] triaxial and consolidation) at several locations. The results of these advanced tests are provided above. Total penetration depths for the SPT borings ranged from approximately 6 feet to 34 feet below the mudline. The geotechnical boring logs are provided in the RD Data Report (Shaw/Anchor 2006a).

2.2.7 Cone Penetration Tests

Nine CPTs were also performed in OUs 3 and 4 to investigate the stratigraphy of the subsurface. Penetration depths of the CPTs ranged from 14 to 47 feet below the mudline. Results of the CPT borings are provided in graphical format in the RD Data Report (Shaw/Anchor 2006a).

2.3 Extent of PCBs in Lower Fox River Sediments

As discussed in the RD Work Plan and accompanying SAP/QAPP documents, a primary objective of the RD evaluation was to conduct sufficient sampling and analysis, and follow-on geostatistical evaluations, to reliably delineate the areal and vertical extent of sediment PCB concentrations exceeding the 1 ppm RAL specified in the RODs. Sampling and analysis data gaps to inform this evaluation were addressed during the 2004 and 2005 field programs described above, which resulted in PCB analysis of nearly 10,000 sediment samples collected from more than 1,300 core locations in the river. RD sampling locations are depicted in Figure 2-1.

Using the considerable RD data collected as outlined above, the Response Agencies, Participating Companies, and their respective consultants participated in series of collaborative workgroup discussions to evaluate and recommend geostatistical methods to define "neat line" dredging depths and elevations, and appropriate target overdredge requirements to inform the ROD Remedy dredge plan design. The results of these evaluations are provided in technical memoranda submitted under separate cover (Anchor and LTI 2006a, 2006b, and 2006c), and are summarized below.

2.3.1 Geostatistical Delineation of Remediation Boundaries

Geostatistical methods were used to delineate the depth of contamination (DOC) boundary in OUs 2 to 5, defined as the boundary beyond which sediment PCB concentrations are at or below the RAL of 1 ppm as specified in the RODs. It is important to note that both the bottom and sides of the "neatline" remediation prism, as determined using geostatistical methods, will be enlarged during the design and construction process to account for overdredging allowances (e.g., six inches below the required dredging depth), slope stability issues (i.e., "layback" requirements) to avoid oversteepening and failure of cut surfaces, and in general, discretizing an irregular surface to make constant-elevation or constant-slope dredging units. This expansion of the "neatline" remediation volume ranged from approximately 30 to 60 percent as a result of such engineering factors, with higher expansion in relatively thin-cut areas (see Section 3). This expansion of the neatline volume, with the addition of an overdredge allowance and horizontal shaping of the dredge cuts, was not calculated into the dredge volumes stated in the RODs signed by WDNR and USEPA in December 2002 and June 2003.

2.3.1.1 Interpolation Methods

Two types of interpolation methods were used to delineate the "neatline" remediation prism, and associated areas, volumes, and contaminant distributions:

- Full Indicator Kriging
- Thiessen Polygons

Each of these interpolation methods is briefly outlined below.

Full Indicator Kriging. A primary advantage of kriging over the Thiessen polygon method is that kriging provides quantitative estimates of statistical confidence and uncertainty at different configurations of the remediation boundary. Full indicator kriging (FIK; see Goovaerts 1997, pp. 293) was the method used to estimate depth of contamination in OUs 2 to 5. FIK estimates a probability distribution function for the depth of contamination (relative to the 1 ppm RAL) at every location in the study area based on information from surrounding cores. These local probability distributions make it possible to map the depth and spatial extent of contaminated sediment for any given probability of occurrence (i.e. level of significance [LOS]). For use on the Lower Fox River,

FIK has been shown to be as accurate as or better than other kriging methods, such as ordinary kriging and indicator kriging (see Anchor and LTI 2005a, 2005b, and 2005c).

Key advantages of the FIK method include the following:

- FIK uses the local distributions of DOC data to predict the probability distribution of DOC at each location. This provides a more accurate assessment of the uncertainty in DOC predictions compared to some other kriging methods (e.g., ordinary kriging), which generate uncertainty estimates based mainly on the distribution and spacing of the samples (i.e. grid density);
- FIK does not require any distributional assumptions, and can be applied whether or not the data conform to normal or other statistical distributions; and
- The analysis of Lower Fox River data has shown that FIK results in less local bias (i.e., less tendency to overestimate shallow contamination and underestimate deep contamination), relative to ordinary kriging (Anchor and LTI, 2005a, 2005b, and 2005c).

Thiessen Polygons. Although FIK is the preferred method for delineating the remediation boundary, Thiessen polygons are useful in some applications. This is an empirically based method which exactly preserves analytical data values, and is based on the assumption that the value observed at a sampling station applies uniformly throughout the Thiessen polygon area associated with that sampling station. The sides of the polygon are defined by the perpendicular bisectors through the mid-points of the distances to the next nearest sampling stations.

Thiessen polygons were used to map distributions of maximum PCB concentrations and mass per unit area in OUs 3 and 4 (see Figures 2-14 through 2-17), because FIK does not preserve information on continuous variables. Ordinary kriging methods were not used to map concentration and mass because these parameters tend to follow lognormal distributions, and biases may be introduced when data are log transformed during kriging. Thiessen polygons were also used to map areas potentially subject to TSCA disposal requirements (see Section 2.4 below), as such higher concentration areas are represented only a few percent of the total volume of sediments in OUs 2 to 5, and kriging may introduce biases when estimating extreme values in such a population.

2.3.1.2 Statistical Significance Levels

A key measure of the uncertainty associated with the estimation of remedial volumes and areas is the statistical "level of significance" (LOS), i.e. the probability of exceeding the RAL at a specific location within the river along a prospective remediation boundary. Several different levels of significance (LOS = 0.5, 0.4, 0.3, 0.2, and 0.1) were evaluated to determine the most accurate and least biased surface to use in RD (see Section 2.3.1.3, below).

Type I Error. In this application, the LOS is the estimated fraction of sediment along the remediation boundary that may contain PCB concentrations above the 1 ppm RAL, which may not be fully captured in the first remedial action effort. In statistical terms, characterizing sediment as generally below the RAL when there may be a fraction of sediment that exceeds the RAL is termed a Type I error (or "false negative").

Type II Error. In contrast to the Type I error, characterizing sediment as generally above the RAL when there may be a fraction of sediment that is below the RAL is termed a Type II error (or "false positive"). Type II errors may result in unnecessary remediation of clean sediment. The costs associated with Type II errors could include: straining of disposal site capacity, burdening the local community and infrastructure with a prolonged cleanup process, short-term environmental effects resulting from unnecessary in-water construction activities, and potentially ineffective use of cleanup resources with relatively little risk reduction.

To the extent practicable, the LOS should be optimized to balance Type I and Type II errors, taking into account the consequences of each type of error. Typically, reducing Type I errors results in a commensurate increase in Type II errors. Whereas Type I errors can be addressed through post-dredge confirmation sampling and supplemental response actions, as needed (e.g., cover, contingent capping, second-pass dredging), a Type II error cannot be reversed. As described in Section 2.3.1.4, cross-validation metrics are used to evaluate Type I and Type II errors, and to select an appropriate LOS for use in RD.

2.3.1.3 Initial Estimates of Remediation Areas and Volumes

Preliminary estimates of "neatline" remediation areas and volumes as determined by FIK at various levels of significance (LOS) are summarized in Table 2-12. Significantly larger potential remediation areas and volumes result from the use of more stringent significance levels to ensure with higher degrees of certainty that initial remedial actions (e.g., first-pass dredging) will remove all sediments above the RAL. As discussed in the next section, the use of more stringent significance levels comes at the cost of remediating larger volumes of material already below the RAL, and does not improve the accuracy of the remediation plan.

2.3.1.4 Selection of Design Level of Significance

Cross validation was performed on the kriging results to provide quantitative metrics to compare the reliability and accuracy of the various significance levels. "Drop one" cross validation consists of removing each data point, one at a time, and using the surrounding data points to interpolate an estimated value for the missing point, then repeating this process for every data point in the data set. The difference between the "drop one" kriging prediction and the actual data value at each location provides important information about model performance and predictive accuracy.

Cross-Validation Metrics. Certain validation metrics are more amenable to binary variables—i.e., "hit" (locations with PCBs above the 1 ppm RAL) versus "non-hit" (locations which do not exceed the RAL). Other metrics are more amenable to continuous variables, specifically, the depth of contamination which can assume a continuous range of values.

Table 2-12. Estimated "Neatline" Areas and Volumes above 1 ppm PCBs

	"Neatline" Remediation Area (Acres)				
Significance Level:	**0.5**	**0.4**	**0.3**	**0.2**	**0.1**
OU 3	230	297	378	476	586
Percent Increase		*29%*	*64%*	*107%*	*155%*
OU 4A	608	647	683	720	773
Percent Increase		*6%*	*12%*	*18%*	*27%*
OU 4B	305	333	362	394	422
Percent Increase		*9%*	*19%*	*29%*	*38%*
OU 4 – Total	913	980	1,045	1,114	1,195
Percent Increase		*7%*	*14%*	*22%*	*31%*
	"Neatline" Remediation Volume (Cubic Yards)				
Significance Level:	**0.5**	**0.4**	**0.3**	**0.2**	**0.1**
OU 3	309,832	434,099	588,136	788,674	1,061,854
Percent Increase		*40%*	*90%*	*155%*	*243%*
OU 4A	2,932,000	3,506,000	4,137,000	4,895,000	6,001,000
Percent Increase		*20%*	*41%*	*67%*	*105%*
OU 4B	1,675,000	2,049,000	2,550,000	3,132,000	3,887,000
Percent Increase		*22%*	*52%*	*87%*	*132%*
OU 4 – Total	4,607,000	5,555,000	6,687,000	8,027,000	9,888,000
Percent Increase		*21%*	*45%*	*74%*	*115%*

The following metrics were calculated:

- Sensitivity – Number of locations correctly classified as Hits/Total actual Hits
- Specificity – Number of locations correctly classified as Non-hits/Total actual Non-hits
- False Positive – Number of Non-hits classified as Hits/Total estimated Hits
- False Negative – Number of Hits classified as Non-hits/Total estimated Non-hits
- Percent Correct – Number of locations correctly classified/Total number of locations.

In general, the objective is to balance sensitivity and specificity, and false positive and false negative errors. These two metrics pairs are opposed, such that an improvement in one index is coupled with a reduction in the other index. Another objective is to optimize the reliability or the "percent correct" of the estimates.

The following metrics were calculated for DOC, a continuous variable:

- Root Mean Squared Error (RMSE) = sqrt [sum(observed – predicted)2/number of locations]
- Mean Absolute Deviation (MAD) = average absolute value (observed – predicted)
- Bias = sum(observed – predicted)/number of locations = average (observed – predicted)

The objective is to minimize the RMSE, MAD, and bias, which are measures of deviations between predicted and observed values, i.e., the accuracy of the predictions.

Typically, false positives increase and false negatives decrease as significance levels become more stringent (i.e., as LOS decreases). Similarly, sensitivity increases and specificity decreases as significance levels become more stringent. These two pairs of metrics are opposed, such that a gain in one metric is typically accompanied by a loss in the other.

Optimum Level of Significance. Cross-validation metrics for the project area are summarized in Table 2-13. The highest percent correct predictions are observed at a significance level of 0.5, and the least biased estimates are observed at significance levels between 0.5 and 0.4. At more stringent significance levels, positive bias increases by two to six inches in OU 3, and by one to two feet in OU 4; both the RMSE and the MAD also rise, indicating a deterioration of accuracy.

Table 2-13. Cross Validation Metrics for Full Indicator Kriging

	Significance Level				
	0.5	**0.4**	**0.3**	**0.2**	**0.1**
OU 3					
False Positives	46%	52%	55%	60%	63%
False Negatives	21%	17%	14%	11%	11%
Sensitivity	49%	65%	76%	86%	89%
Specificity	83%	71%	62%	47%	37%
Percent Correct	73%	70%	66%	58%	52%
RMSE (feet)	2.2	2.2	2.4	3.0	3.5
MAD (feet)	0.3	0.3	0.4	0.5	0.6
Bias (feet)	-0.1	0.0	0.2	0.3	0.5
OU 4A					
False Positives	15%	20%	24%	27%	31%
False Negatives	22%	16%	10%	9%	10%
Sensitivity	88%	93%	97%	98%	98%
Specificity	73%	60%	49%	37%	25%
Percent Correct	83%	81%	79%	76%	71%
RMSE (feet)	2.2	2.2	2.4	3.0	3.5
MAD (feet)	1.3	1.4	1.5	2.0	2.5
Bias (feet)	-0.3	0.2	0.7	1.5	2.1
OU 4B					
False Positives	17%	21%	24%	26%	28%
False Negatives	25%	25%	25%	25%	24%
Sensitivity	89%	90%	93%	94%	95%
Specificity	64%	55%	44%	37%	30%
Percent Correct	80%	78%	76%	74%	73%
RMSE (feet)	2.5	2.7	3.0	3.4	3.8
MAD (feet)	1.7	1.8	2.1	2.4	2.9
Bias (feet)	-0.3	0.3	0.9	1.6	2.4

In **OU 4A**, false positives and false negatives are balanced between significance levels of 0.5 and 0.4. In **OU 4B**, the optimum balance occurs at a significance level of 0.5 because the false negative rate shows no improvement at more stringent significance levels. For each incremental step up in significance in OU 4A and OU 4B (e.g., from 0.5 to 0.4, and from 0.4 to 0.3), specificity deteriorates

by about 10 to 15 percentage points, whereas sensitivity increases by only 1 to 6 percentage points. Therefore the deterioration of specificity outpaces the gain in sensitivity. Even at significance levels of 0.5 and 0.4, sensitivity is relatively high (88 to 93 percent).

In **OU 3**, which accounts for less than ten percent of the total remediation volume (see Table 2-12), cross-validation metrics showed somewhat lower overall performance relative to OU 4. In particular, false positive predictions in OU 3 are about 30 percent higher, sensitivity is about 10 to 40 percent lower, and percent correct predictions are about 10 to 20 percent lower compared to OU 4. The lower performance metrics in OU 3 are probably caused by generally lower PCB concentrations and more subtle concentration gradients, i.e., PCB concentrations throughout much of OU 3 are very close to the RAL, and fluctuate slightly above and slightly below the RAL. It is expected that further improvements in the cross-validation metrics for both OU 3 and OU 4 will be realized during evaluation of data from the significant additional sediment cores collected in 2005. Although the 2005 coring data were not included in the detailed geostatistical analysis included in this BODR, these data will be incorporated in the 30 Percent Design.

Considering all of the above, a remediation prism based on a significance level of 0.5 provides the best performance and reliability, as evidenced by the following:

- Low bias;
- Minimum RMSE and MAD;
- Maximum percent correct predictions;
- Optimal balance of false positives and false negatives (OU 4); and
- Optimal balance of specificity and sensitivity (OU 4).

In addition to the overall strong performance at the 0.5 significance level, false negatives will be further reduced and sensitivity will be further enhanced by the implementation of a 0.5-foot overdredging requirement and post-remediation confirmation sampling (see Section 3).

2.3.2 PCB Mass Estimates

The total mass of PCBs within the Lower Fox River was estimated based on the results of the 2004 and 2005 RD sampling and analysis programs using the equations shown below. Additional details regarding the PCB mass calculations are provided in Appendix A.

$$\text{PCB Mass per core} = PCB \cdot \rho \cdot l \cdot A$$

where:

PCB = Sample PCB concentration, mg/kg (dry weight basis)
ρ = dry density of sediment, g/cm^3
l = sample length, cm
A = Thiessen polygon area represented by core.

Table 2-14 presents prior estimates of the total PCB mass in OUs 3 and 4 from the 2003 ROD, along with current estimates of PCB mass developed using the 2004 and 2005 RD data. The RD investigations provided new information relative to both the distribution and magnitude of PCB concentrations and sediment properties. For example, the RD estimates of PCB mass presented in this BODR were based on a considerably greater PCB sample data density (nearly 10,000 samples collected in 2004/2005, versus 1,300 available at the time of the 2003 ROD). The mass estimates presented in this BODR also incorporated more detailed moisture content and specific gravity measurements, which were subsequently converted to dry bulk density through geotechnical phase relationships, as outlined above. The 2004/2005 RD data revealed that the average dry density of soft sediments in the river is approximately 0.45 g/cm^3 (i.e., 13 percent less than the average density of 0.52 g/cm^3 assumed in the 2003 ROD). Based on this revised sediment density, the current estimate of PCB mass in the river is less than the PCB mass estimated in the 2003 ROD, as shown in Table 2-14.

Table 2-14. Lower Fox River PCB Mass Estimates

Operable Unit	Estimated PCB Mass		
	ROD Estimate [(c)]	BODR Estimate (ROD Sediment Density) [(c)]	BODR Estimate (BODR Sediment Density) [(d)]
	(kg)	(kg)	(kg)
OU 2 [(a)]	31	160	130
OU 3	1,250	1,190	1,000
OU 4	26,650	24,000	19,950
OU 5 [(b)]	Not Estimated	420	360
Site Total	**27,930**	**25,770**	**21,440**

(a) Deposit DD only

(b) Portion near mouth of Fox River only

(c) Estimates of PCB mass in the 2003 ROD assumed a depth-averaged sediment density of 0.52 g/cm^3

(d) Estimates of PCB mass for the BODR are based on considerable new data, including correction of density data for core compaction per RD Work Plan (Shaw/Anchor 2004a).

The 2004/2005 RD sampling data also revealed substantive spatial differences in the extent of sediment PCB contamination, relative to conditions contemplated in the 2003 ROD. These differences are discussed in Sections 2.3.3 and 2.3.4 below.

2.3.3 Spatial Extent of PCBs Exceeding the RAL

The spatial distributions of PCB mass in OUs 3 and 4 are presented on Figures 2-14 and 2-15, respectively, using Thiessen polygons. The spatial distributions of maximum PCB concentrations (based on six-inch core intervals) in OUs 3 and 4 are presented on Figures 2-16 and 2-17, respectively, using Thiessen polygons. Plan-view maps of the spatial extent of PCB concentrations above the RAL in OUs 3 and 4 (i.e., the "footprint" of the remediation boundary) are presented on Figures 2-18 and 2-19, respectively, using full indicator kriging with significance levels of 0.5, 0.4, and 0.3. Figures 2-14 through 2-17 provide important information on the PCB mass inventory in the

sediments which is not captured in the indicator kriging maps on Figures 2-18 and 2-19, because indicator kriging discretizes data in terms of whether or not the RAL is exceeded, but does not convey information on the magnitude of the exceedance (i.e., how high the PCB concentrations are relative to the RAL). Together, these various sets of maps characterize the spatial distribution of PCBs in the project area, as discussed below.

2.3.3.1 OU 3 (and OU 2 Deposit DD)

The following observations regarding the extent of contamination are evident from inspection of Figures 2-14, 2-16, and 2-18:

- There is a general, large-scale gradient toward higher concentrations and more extensive areas of contamination in a downstream direction in OU 3. The bulk of the PCB mass (peaking at greater than 20 ppm, and greater than 5 g/m^2), and the most extensive areas above the RAL are found in the most downstream reach of OU 3, within about 10,000 feet of the De Pere Dam. In the upper reaches of OU 3, areas of contamination are patchy and discontinuous, and concentrations are relatively low (typically at or below 1 ppm), evidenced by low PCB mass inventory.
- The highest PCB concentrations and the highest mass inventory are concentrated in narrow and elongated features aligned with the flow direction. These features appear to be former river channels or "thalwegs" where historical deposition of PCBs may have been concentrated.

2.3.3.2 OU 4 (and OU 5 at LFR River Mouth)

The following observations regarding the extent of contamination are evident from inspection of Figures 2-15, 2-17, and 2-19:

- The highest PCB concentrations and mass inventory, peaking at greater than 50 ppm and greater than 20 g/m^2, were encountered at the head of OU 4A; at depth below the De Pere turning basin; in the unmaintained navigation channel in OU 4A and in certain off-channel deposits, and at depth in the vicinity of SMU 56/57 and the Fort Howard turning basin. Variations in PCB concentration profiles with depth between different reaches of OU 4 are discussed below.
- Contiguous areas with relatively clean sediments below the 1 ppm RAL are found in relatively shallow water bench areas along both east and west banks of OU 4A; along a one-mile reach in the navigation channel of OU 4B above and below the East River; and in lateral deposits on the river-mouth delta in Green Bay, several hundred feet outside of the navigation channel.

2.3.4 Depth of Contamination (DOC) Relative to the RAL

The depth of contamination in OUs 3 and 4 is presented on Figures 2-20 and 2-21, respectively, using full indicator kriging with a significance level of 0.5. These DOC maps were subtracted from the

mudline elevation to generate an elevation surface of the bottom of contamination, and used by the design team to develop the dredge plans (see Section 3).

2.3.4.1 OU 3 (and OU 2 Deposit DD)

The following observations regarding depth of contamination are evident from inspection of Figure 2-20:

- There is a general, large-scale gradient from shallow to increasingly deeper contaminated sediment thickness in a northward direction, culminating in the thickest accumulations (up to 2 feet thick) just upstream of the De Pere Dam.
- The thickest contaminated sediment accumulations are concentrated in narrow and elongated features aligned with the flow direction, possibly present-day or former river channels or "thalwegs"; these thicker sediment accumulations generally coincide with areas of higher PCB concentration and mass inventory (compare to Figures 2-14 and 2-16)

2.3.4.2 OU 4 (and OU 5 at LFR River Mouth)

The following observations regarding depth of contamination are evident from inspection of Figure 2-21, and highlight some of the more important differences in the spatial patterns of sediment contamination between different river reaches, as characterized by the RD sampling. Several of the more substantive differences in the characterized extent of contamination, relative to site conditions contemplated in the RI/FS and OU 3 to 5 ROD, are also summarized below:

- The thickest accumulations of contaminated sediment are found in the unmaintained navigation channel of OU 4A, including the De Pere turning basin; and in the vicinity of SMU 56/57 and the Fort Howard turning basin. In parts of these areas, contaminated sediment thicknesses are greater than 10 feet.
- Areas where contaminated sediments are relatively thin (i.e., less than 2 feet thick) are found along both east and west banks in OU 4A; in portions of the navigation channel and side-slope areas in OU 4B; and in lateral deposits outside of the navigation channel on the river-mouth delta in Green Bay.
- In most cases, the thickest contaminated sediment accumulations also correspond to areas where the highest PCB concentrations and mass inventory are found (compare to Figures 2-15 and 2-17); one notable exception, however, is the southwest corner of OU 4A (RM 6.6), where relatively high PCB concentrations (ranging between approximately 10 and 3,000 ppm; see Figure 2-22) were detected in relatively shallow deposits of only a few feet thick.
- Substantial thicknesses (up to 13+ feet) of contaminated sediments were detected in several developed shoreline areas of OU 4, such as immediately adjacent to the SMU 56/57 demonstration project.
- Similarly, deeply buried sediments (between approximately 6 to 13 feet below mudline) were detected at depth below the bottom of the authorized federal navigation channel. Representative sediment concentration profiles in the middle reaches of OU 4A (RM 4.2) and in the Fort Howard turning basin (RM 3.0) are depicted in Figures 2-23 and 2-24,

respectively. These profiles reveal that relatively cleaner sediments overlie higher concentration deposits present at greater depth below the bottom of the navigation channel. These site conditions, which are consistent with stable subsurface sediment deposits that have not been reworked over time, and which were not envisioned at the time of the RODs, have important implications for the design of practicable cleanup remedies, as discussed in more detail in Section 5.

2.4 Characterization of Material for Beneficial Use and Disposal Purposes

As discussed in the RD Work Plan, securing implementable and cost-effective transport and disposal options will likely be critical components of the remedial action in OUs 2 to 5. A range of disposal options including NR 500 landfills and other facilities that provide dewatering and/or disposal are considered in this BODR, and will be considered further during subsequent stages of RD. Potential beneficial use options also exist for sediments containing relatively low concentrations of PCBs.

An important component of RD is to determine the volume of dredged sediment that may be suitable for a range of possible beneficial use options, as well as the volumes that will require disposal in an NR 500 landfill or TSCA licensed facility. The section below describes the methodology for making such determinations, and summarizes the estimated extent and volume of sediments that may be subject to TSCA regulation if removed and disposed, consistent with Addendum No. 3 to the RD Work Plan.

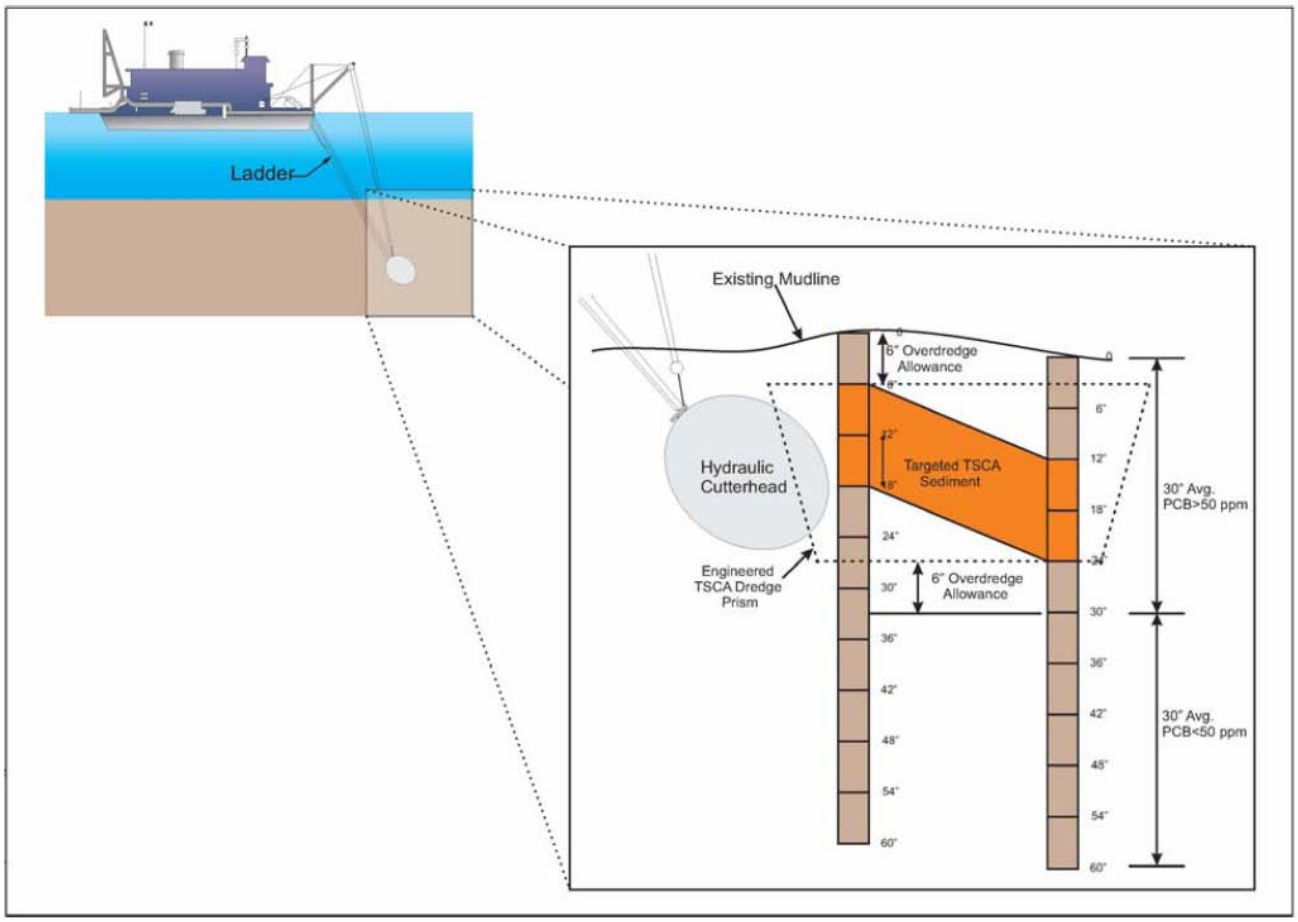
2.4.1 Dredge Plan Considerations

Characterization of sediments for beneficial use or disposal needs to take into account actual dredging conditions. During implementation of the remedial action, dredging equipment accuracies and tolerances limit the ability of a contractor to remove precisely a “neatline” volume because the neatline depth/elevation is a complex three-dimensional surface which is fit to a series of constant-elevation or constant-slope dredge material management units for implementation. As a result, the dredging contractor is not capable of removing only the neatline volume, but instead ultimately removes additional (non-neatline) sediment. The quantity and extent of non-neatline sediment removed depends upon the complexity of the neatline surface and how carefully the required dredge prism is designed to minimize removal of non-neatline material. There is a trade-off between minimizing excess volumes and maximizing constructability when designing a dredge prism— a dredge prism that minimizes excess volume (i.e., that remains close to a complex neatline surface) is generally less constructable (see Section 3.3).

Because additional non-neatline sediment will be removed, the in situ concentration of this sediment should also be taken into account when delineating target areas for specific beneficial use or disposal purposes (e.g., dredged material potentially subject to TSCA disposal regulations). Therefore, for the purposes of determining the applicability of TSCA disposal requirements, it is important to identify a reasonable assumption to use for the additional thickness of non-target sediment that will be removed

as part of the removal of target materials. The thickness of sediment removed outside the neatline area has two main components: (1) thickness of sediment between the neatline surface and the dredge prism surface, and (2) thickness of the overdepth allowance. The relationship of neatline and non-neatline surfaces is schematically shown on Figure 2-25.

Figure 2-25 Typical Dredge Prism Schematic for Sediment Characterization Purposes



In transforming the complex and variable neatline surface into an implementable dredge plan design comprised of constant-elevation or constant-slope dredge material management units, it is necessary to remove additional material beyond the neatline surface. Based on past experience on other similar environmental dredging projects, the average thickness of non-neatline sediment removed, excluding allowable overdepth, is typically 0.5 feet or greater. Allowable overdepth is defined as additional material removed from below the required dredge prism to ensure complete removal of the required dredge prism. Allowable overdepth is necessary due to dredging equipment precision and tolerances.

With careful vertical control and/or specialized dredging equipment, it should be possible to maintain an overdepth allowance of 0.5 feet, which is as small as practicable using modern equipment. Combining these two components (dredge plan design plus overdepth) results in additional sediment thicknesses above and below the neatline surface (on average) that will be removed along with the target materials.

When targeting the removal of a 0.5-foot (6-inch) layer of subsurface sediments (e.g., a buried layer of sediments with greater than 50 ppm), on average an additional one foot of sediment above and below the neatline (i.e., 2.5 feet total thickness) is the smallest practicable amount of sediment that can be removed efficiently. The 2.5-foot thickness also corresponds to the typical cutterhead diameter of a 12-inch hydraulic dredge, which mixes sediments across this 2.5-foot interval during the dredging process. (See Sections 3.2.1 and 5.2.3 discussions of equipment selection in OUs 2 to 5.) Thus, for the purpose of characterizing dredged material for beneficial use or disposal purposes based on in situ sediment conditions, 6-inch sample depth data were averaged across non-overlapping 2.5-foot (30-inch) sediment intervals beginning at the mudline (Figure 2-25). For example, if the 2.5-foot vertically averaged sediment concentration exceeds 50 ppm, neatline and associated sediments (including overdredge allowances) dredged from this unit would be subject to TSCA disposal requirements. This relatively straightforward designation procedure uses detailed sediment sampling data to consistently designate sediments potentially subject to TSCA disposal requirements that result from successive cuts using modern dredging equipment as may be applied to OUs 2 to 5 (e.g., 12-inch hydraulic dredges or similar environmental dredging equipment).

2.4.2 Methodology to Delineate Regulated Materials for Disposal Purposes

For designating dredged material for specific beneficial use or disposal purposes, 6-inch sampling depth data from individual RD sediment cores (including 2004 and 2005 sampling events) were vertically composited across non-overlapping 2.5-foot (30-inch) sediment intervals beginning at the mudline (Figure 2-25). The 2.5-foot vertical interval includes any overdredge and smoothing of the neatline needed to construct a practicable dredge prism. Once all cores were analyzed using this vertical compositing method, the horizontal extent of sediments exceeding a specific beneficial use or disposal criterion was delineated using Thiessen polygon analysis. The horizontal extent of composited sediments exceeding 50 ppm PCBs and anticipated to require disposal in a TSCA-licensed landfill is depicted on Figure 2-26, which represents an estimated volume ranging between approximately 170,000 and 210,000 cy, subject to final dredge plan designs. The upper sediment volume range derived from this analysis that may potentially be subject to TSCA disposal requirements (210,000 cy) was used in this BODR. This analysis did not identify any sediments in OU 2, OU 3, or OU 5 that are anticipated to require disposal in a TSCA-licensed landfill

(Figure 2-26). Additional discussion of potential beneficial use and disposal considerations is provided in Section 4.

2.5 Potential for Recontamination

There are three potential sources of recontamination that may affect the overall performance of the OU 2 to 5 remedial action, each of which will all be addressed by the design:

- Ongoing downstream transport of PCB-contaminated sediments in the Lower Fox River;
- Dredging-related resuspension and residuals; and
- Ongoing PCB loads.

Each of these potential sources is briefly reviewed below.

2.5.1 Ongoing Downstream Transport of PCB-Contaminated Sediments in Lower Fox River

Remedial actions will be sequenced as practicable from upstream to downstream, and/or by dredging the most contaminated locations first to minimize the potential for recontamination of newly remediated areas.

2.5.2 Dredging-Related Resuspension and Residuals

Sediment resuspension and/or post-dredge residual contamination is inevitable when dredging contaminated sediments due to the inability of even the most modern 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. Post-dredge sediment residuals associated with dredge-induced resuspension and other transport processes likely represents an even larger potential source of recontamination of newly remediated areas. By these processes, sediment can be transported hundreds of feet from the dredge before settling. Two management approaches will be implemented to address this potential for contamination from dredging residuals:

A. Specifying appropriate best management practices (BMPs) during dredging to limit residual contamination sources during dredging operations; and

B. Employing methodologies to address residual contamination after the completion of dredging.

Best Management Practices. BMP controls will be developed as part of the RD 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 bed scour from vessel propeller wash. 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.

Post-Dredge Residuals Management. The RODs require dredging until either all sediment above the 1 ppm RAL is removed or the SWAC in a particular OU is met. If these conditions are not met, additional dredging or placement of a residuals sand cover on dredged areas may be implemented. Based on the relative impracticability of additional dredging actions to remove the high water content residual layer, residual sand covers are likely the more realistic post-dredge residual management option. Dredge residual management considerations are discussed in more detail in Section 3.6.4.

2.5.3 Ongoing PCB Loads

Data collected during the RI/FS suggest that PCB loading to the Lower Fox River from external (non-sediment) sources has been significantly reduced from historical levels. 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. However, potential sources of ongoing PCB loads to the Lower Fox River continue to exist and may affect the rate and/or magnitude of future PCB reductions in the post-construction period. The significance of these non-sediment sources may only become known in the context of future, long-term, post-construction monitoring of water and tissue concentrations.

A brief summary of ongoing sources of PCB loading to the Lower Fox River is provided below.

2.5.3.1 Lake Winnebago

LTI evaluated water column PCB data in Lake Winnebago and found the vast majority of the available data were non-detect with detection limits typically around 5 ng/L, meaning actual concentrations were somewhere between 0 and 5 ng/L, and average annual PCB export from Lake Winnebago was between 0 and 19.6 kg/year. Previous measurements made during the Green Bay Mass Balance Study found that PCB concentrations in Lake Winnebago were of the same magnitude as PCB concentrations in field blanks, and therefore could not be resolved. In the absence of detectable analytical results, it is difficult to speculate on the magnitude of PCB loads from Lake Winnebago and the predominant source of PCBs in the watershed, if any. Forthcoming baseline monitoring using high resolution PCB analysis techniques may help to characterize regional background PCB concentrations in Lake Winnebago.

2.5.3.2 Tributary Streams and Urban Stormwater Runoff

Non-point source PCB loads were estimated in TM3a based on estimated watershed flows and measured PCB concentrations in tributaries and stormwater. Sediment samples obtained from 5 storm sewer catch basins upstream of the De Pere Dam had a mean PCB concentration of 0.38 ppm, whereas sediments from 10 storm sewer catch basins downstream of the De Pere Dam had a mean PCB concentration of 0.15 ppm. Based on these data, annual watershed PCB loads were estimated to range from 0.57 to 2.13 kg/year for the reach between Lake Winnebago and De Pere Dam, and 0.22 to 0.89 kg/year for De Pere Dam to Green Bay (Steuer et al. 1995).

In a separate data set, PCBs were detected in 10 to 20 percent of samples collected during a study of four urban Wisconsin streams and 10 urban storm drains (Bannerman 1996). In this study, the mean stormwater PCB concentration was 110 ng/L; however, the median stormwater PCB concentration was nondetect. Using the mean concentration of 110 ng/L, along with the estimate of watershed flow from urban areas in TM2a, non-point source PCB loads to the Lower Fox River were estimated. The resulting estimated PCB loads were 4.4 kg/year for the river upstream of the De Pere Dam and 2.9 kg/year downstream of the dam.

2.5.3.3 Atmospheric Deposition

The net exchange of PCBs at the air-water interface is driven by gas-liquid phase partitioning and volatilization. These processes are dependent on the PCB concentrations in both the air and water as dissolved PCBs in the water attempt to equilibrate with the concentrations in the atmosphere. It is expected that normal concentration gradients will result in a net loss of PCBs from the river to the atmosphere rather than the reverse. Furthermore, it is expected that atmospheric particulate deposition to the Lower Fox River may be assumed to be negligible due to the relatively small surface area of the river relative to the surface area of the contributory drainages. To the extent atmospheric deposition onto the watersheds may be significant, this source is captured in the analysis of tributary loads and stormwater runoff. In summary, both particulate and dissolved atmospheric loads to the Lower Fox River are assumed to be negligible.

2.5.3.4 Arrowhead Park Landfill

Steuer et al. (1995) estimated the groundwater PCB load for the Arrowhead Park landfill at 0.013 kg/yr (0.035 g/day). This estimate was based on dissolved PCB concentrations in groundwater samples from monitoring wells in the landfill (ranging from nondetect to 1.98 ng/L), and the estimated rate of groundwater flow through the containment dike of the landfill. The estimated load contributed by particulate runoff from the landfill was assumed to be zero.

2.5.3.5 Other Point Source Discharges

Technical Memorandum 2d (TM2d) developed estimates for all permitted point source discharges to the Lower Fox River based on Discharge Monitoring Reports (DMRs), Cooperative Mill Surveys, production records, and other information. These point sources included primarily paper mills and sewage treatment plants. The total estimated cumulative load to the Lower Fox River from all point sources ranged from 3.7 to 23.5 kg/yr. PCB loads from point sources are anticipated to continue to decline.

2.5.3.6 Summary of Findings

The estimated PCB loads to the Lower Fox River from various point and non-point sources are summarized in Table 2-15.

Table 2-15. Summary of External PCB Loadings to the Lower Fox River

External PCB Source	Range of Estimated Annual PCB Load, 1989-95 (kg/year)	Expected Trends Beyond 1995
Lake Winnebago	0 to 19.6	Declining, unless ongoing point sources exist
Arrowhead Park	0.013	Constant, negligible
Tributaries and Runoff	0.8 to 7.3	Declining, unless ongoing point sources exist
Atmospheric Deposition	Negligible	Atmospheric loads are declining
Point Sources	3.7 to 23.5	Declining as residual PCBs in waste paper decline (TM2d)
TOTALS	**4.5 to 50**	

Given the magnitude and uncertainty associated with PCB loads from Lake Winnebago, tributaries, urban stormwater runoff, and point sources, these sources may deserve further consideration in assessing their impact on the long-term effectiveness of sediment remediation in meeting RAOs. While the resuspension and dissolution of PCBs from in-place sediments in the Lower Fox River likely represents the largest load source to the river system under present-day conditions, when this source is controlled as a result of the sediment remedial action, the significance of remaining point and non-point sources may become more evident. The significance of these other potential sources may only become known in the context of future, long-term, post-construction monitoring of water and fish tissue concentrations.

2.5.4 Long-Term Monitoring of Sediment, Water, and Fish Tissue

As set forth in the RODs, baseline and post-construction monitoring of the Lower Fox River and Green Bay will 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 remedial action objectives (RAOs); and
- 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 will continue until acceptable levels of PCBs are reached in these environmental media. As set forth in the AOC, long-term monitoring plans and contingency response plans will be developed as part of intermediate RD documents, specifically as part of the Operations, Maintenance, and Monitoring Plan (OMMP). Section 7 of this BODR presents an overview of anticipated monitoring and maintenance measures.

3. ROD REMEDY - SEDIMENT DREDGING

This section discusses the development of the dredge plan for the ROD Remedy. The process to develop the dredge plan included several key steps. In general, the first step was to define site conditions that affect dredging. A general discussion of existing site characteristics was provided in Section 2, and included an initial assessment of how some of the key site characteristics may affect the dredge plan design. This Section provides additional details of site characteristics as they apply to the ROD Remedy dredge plan design. The second step in developing the dredge plan was to select appropriate dredging equipment for these site conditions. The third step was to define the dredge prism based on site conditions, equipment selection, and goals and objectives of the remedial action. The dredge prism is the design template that describes the horizontal and vertical extents of dredging. After the dredge prism was defined, the dredge volumes were calculated. The design team then identified and evaluated potential environmental and operational impacts caused by the dredging and identified appropriate best management practices to minimize those potential impacts. Lastly, the likelihood of contaminant residuals was assessed to identify contingency measures to address water quality and residuals, as appropriate. Each of these steps is discussed in detail in this section.

3.1 Site Characterization Considerations

Table 3-1 presents a summary of the average geotechnical properties of the sediment within the ROD Remedy dredge prism. Appendix A presents a table summarizing the geotechnical properties of all samples that were collected within the ROD Remedy dredge prism during the RD investigations. The sediments targeted for dredging under the ROD Remedy can be generally characterized as soft, silty, clayey sand with an average in situ percent solids of approximately 35 percent by weight. The sediment within the target dredge prism is approximately 42 percent sand, 34 percent silt, and 20 percent clay by weight, with the remaining trace fraction being gravel-sized particles. The data presented in Table 3-1 and Appendix A have been corrected for coring-induced sample compaction, as outlined in the RD Work Plan. In addition, Table 3-1 presents a weighted average estimate of percent solids data to be used in dredge design and disposal volume calculations, which accounts for both the vertical and horizontal representativeness of each sample. The methodology used to calculate the weighted average sediment properties is included in Appendix A. In some locations within the river, a layer of stiff native clay (i.e. “hardpan”) was identified beneath the soft sediment targeted for dredging.

These existing site characteristics were considered during equipment selection and dredge prism design, and are important to developing the specification language to be prepared during remedial design. Site characteristics such as site use and geotechnical characteristics affect key components in the dredge plan, including dredged material transport and dredgeability. In addition, seasonal

restrictions and other institutional factors also affect the dredge plan. Key considerations are discussed below.

Table 3-1. Geotechnical Properties of Sediments Targeted for Dredging Under ROD Remedy

Parameter	OU 2/3	OU 4/5	OU 2-5
Fines Content (% Finer than No. 200 Sieve)			
Avg.[(a)]	62%	53%	55%
Std. Dev.	32%	25%	27%
Percent Solids by Wt. (%)			
Avg.[(b)]	32%	36%	35%
Std. Dev.	18%	16%	16%
Dry Density (pcf)			
Avg.[(b)]	25	28	28
Std. Dev.	24	20	20

Notes:
(a) Numerical average of measured data
(b) Weighted average of measured data (See Appendix A)

3.1.1 Dredged Material Transport Considerations

The available transport options influence the dredge plan. Some of the disposal site factors which may dictate the type of dredged material transport included: 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. The feasibility of hydraulic or mechanical transport to a disposal site, in turn, influences the dredge plan design.

Given the quantity of sediment to be hydraulically dredged, dewatered, and disposed of under the ROD Remedy, the options available for transport and disposal of the material are limited, as discussed further in Section 4. Because the ROD Remedy specifies hydraulic dredging as the primary method for dredging, an in-depth analysis of transport options associated with the selected method of dredging is not required for this BODR. However, this section summarizes some key criteria that will need to be addressed in the specifications during later stages of RD. Furthermore, Section 4 provides a discussion of the evaluation of available disposal facilities for the ROD Remedy.

Hydraulic dredging requires the use of floating or submerged pipelines to hydraulically transport dredged material in a slurry, or fluidized form. Floating pipelines will be used for the majority of the over-water distance. Submerged pipelines will be used if the pipeline has to cross the active federal navigation channel, or cross active piers, boat launches and other high use areas. On land, the pipeline will use available easements (discussed in Section 4). For long pumping distances, booster

pumps are required along the pipeline route. For the ROD Remedy, approximately 9 to 10 booster pumps are anticipated to be necessary along the upland pipeline route.

Barge transport will be used where mechanical dredging is implemented. In general, barge transport is more implementable than a slurry pipeline due to less interference with vessel traffic. However, water depth is the critical factor for whether a barge can be effectively used. For the ROD Remedy, mechanical dredging will be used to remove sediments potentially subject to TSCA disposal requirements, as well as for debris removal and for performing localized higher precision dredging near utilities and obstructions.

The former Shell property adjacent to the Georgia Pacific (GP) West facility (denoted hereafter as the "Shell Property") has been preliminarily identified as a potentially promising staging area location for offloading, dewatering, and stockpiling of the mechanically dredged TSCA materials in OU 4. Staging area requirements and design under the ROD Remedy are discussed in Section 3.7.

Initial remedial design evaluations demonstrated that hydraulically dredging and mechanically pressing the ROD Remedy volume of sediments at the Shell Property and trucking those sediments to a nearby NR 500 landfill facility is not a cost-effective option. With two dredges working concurrently under the ROD Remedy, the amount of required plate and flame press capacity would occupy more land area than that available at the Shell Property (see Section 3.7). Moreover, truck loading, hauling, and unloading operations would have to keep up with dewatered sediment generation at a rate of approximately 2,200 tons per day. Assuming 20 tons per truckload, this would require 110 truckloads per day during daylight hours, which equates to about one truck every seven minutes. Given a typical two hour round trip haul and the need for loading and decontamination of the trucks, accommodating a production rate of 2,200 tons per day with truck transport would pose significant implementation difficulties. (Note that dewatered sediment production would be 24 hours per day, but trucking to landfills would only be permitted during daylight hours.) The combination of limited available staging area and difficult truck transport logistics makes mechanical dewatering and truck transport under the ROD Remedy less cost-effective and less implementable than pipeline transport. (As discussed in Section 5.8, because of lower sediment removal volumes under the Optimized Remedy [relative to the ROD Remedy], mechanical dewatering and truck transport can be used in that situation to achieve overall project efficiencies that are different from the ROD Remedy).

3.1.2 Dredgeability

Dredgeability of the material affects the type and size/power of equipment that the contractor will use for dredging. The material to be removed from OU 3 and OU 4 consists of sands and silts, with some clay component. Using the available grain size data, a preliminary evaluation was performed for this BODR to identify the general size and power range of equipment that will be used to hydraulically

transport the material (e.g., horsepower required for booster pumps), the ability to cut and remove the sediments, and the potential for coarser-grained sediment to inhibit production.

Dredgeability refers to the physical characteristics of the proposed dredge material and how readily the material can be dredged using different pieces of equipment. One 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 RD investigations, including soft sediment poling data, the material within the dredge prism is expected to be very soft, with very low or even zero (i.e., "weight of rods") blow count readings, with buried denser deposits at the native sediment contact interface.

3.1.3 Seasonal Construction Windows and Weather-Related Work Impacts

In-water construction in cold climates can be adversely impacted during the winter, to the point where at times construction work is not possible. As temperatures drop and ice forms, equipment such as dredge and booster pumps will freeze. Ice formation on the river can slow dredge production and can prevent access to certain areas. In addition to the in-water construction activities, upland staging areas, disposal sites, and dewatering activities can experience icing of water surfaces and freezing of mechanical components, resulting in ineffective operation of water treatment and decanting operations, and substantial difficulty or inefficiency in staging and disposal area operations.

To alleviate winter construction impacts, a work window is established during which all in-water work will occur. Outside of this window, major dredging operations will not take place; however, maintenance and more routine, non-weather-dependent activities may occur. The work window for dredging and disposal is envisioned as a 180-day construction window between April/May and October/November to avoid weather-related impacts. Non-weather dependent activities (mobilization, winterization, site preparation, etc.) may be completed during the several weeks immediately preceding or following this in-water work window. Scheduling and sequencing of remedial actions in OUs 2 to 5 is discussed further in Section 6.

In addition to the planned seasonal shut down of major operations during the winter, other seasonal weather patterns could affect the efficiency with which work is completed. Low water levels in the summer or storm events resulting in high wind or current velocities 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. Therefore, the number of active, uncompleted dredging reaches will be limited to the extent possible to reduce the risk during these transient events.

The detailed cost estimates developed in this BODR for the ROD Remedy (Section 8) include the winterizing required for seasonal construction windows as well as contingencies for potential productivity reductions resulting from weather-related impacts. As the contract documents are developed, quality control procedures will be included that will recognize the issues related to weather and seasons and will delineate risk reduction measures that the contractor will be required to implement so as to minimize potential impacts on the project.

3.1.4 Federal Navigation Channel Considerations

As discussed in Section 2, the federal navigation channel in the Lower Fox River extends 7.1 miles from the mouth of the river at Green Bay to the De Pere Dam. However, only the portion between the mouth of the river and the Fort Howard turning basin (denoted OU 4B) is actively maintained. Furthermore, only a portion of the federally authorized width of the channel in OU 4B is actively maintained by dredging, performed by the USACE. Upstream of the turning basin, in OU 4A (extending from the Fort Howard turning basin to the De Pere Dam), the federally authorized navigation channel has been placed in "caretaker" status and is not actively maintained. There is currently no federally authorized channel in any other portion of the Lower Fox River.

The ROD Remedy dredge design is not intended to take the place of regular maintenance of the federal navigation channel, but rather to remove contaminated sediments located within the channel. In some areas within OU 4, removal of these contaminated sediments will involve dredging below the federally authorized navigation depth, while in other areas contaminated sediment dredging will not extend to the federally authorized depth.

The limits of the federal navigation channel provide a fixed set of coordinates within OU 4 (USACE 2005) that can be used as a position reference. Therefore, the centerline of this channel was used as a baseline for the dredge prism design. Cross sections used in conjunction with the geostatistical delineation of PCB contamination to develop the dredge prism were cut perpendicular to the channel centerline.

3.2 Equipment Selection and Production Rates

Equipment potentially available to implement the ROD Remedy was evaluated against design criteria to ensure that there is not a "fatal flaw" factor that will prevent the use of hydraulic dredging technology. While the RODs expressly describe the use of hydraulic dredging, the ROD Remedy design could potentially use both hydraulic and mechanical methods. Due to production efficiencies mechanical dredging is contemplated in the ROD Remedy to remove TSCA sediment (as defined in Section 2.3), as well as debris removal and for performing localized higher precision dredging near utilities and obstructions.

The BODR review of hydraulic dredging equipment as the primary dredging method and mechanical dredging equipment for the TSCA sediment and removal and debris and near obstructions revealed no "fatal flaw" issues that will significantly impact the feasibility of using those methods. This section describes the design criteria against which the selected equipment was compared.

3.2.1 Equipment Selection Process

The ROD specifies the use of an "environmental dredge" (e.g., hydraulic cutterhead, 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 is 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.

The selection of appropriate dredging equipment will ultimately be based on multiple criteria, and may require compromise in order to achieve the best overall results with respect to environmental impact, institutional impact, cost, and scheduling. 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 commercial and recreational vessels transiting the river
4. Water depths
5. Thickness of contamination above 1-ppm PCB
6. Geotechnical properties of sediment targeted for dredging and underlying materials (e.g. presence of hardpan)
7. River current impact on equipment
8. Presence of significant debris
9. Minimization of short-term water quality impacts
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.

3.2.1.1 Availability and Types of Equipment

The availability and types of dredge equipment within the industry were assessed. Both hydraulic and mechanical dredging equipment of the size/capability required for the site were determined to be available for this project.

3.2.1.2 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. For the BODR, an average daily production rate of approximately 4,800 cy/day for hydraulic dredging (assuming two 12-inch hydraulic dredges) and approximately 1,200 cy/day for mechanical dredging of sediments potentially subject to TSCA disposal requirements and debris was identified as potentially feasible for the size and type of equipment anticipated to be used for this project. Production rate considerations are discussed in more detail below. As discussed in Section 1.7.1, remedial actions to date in OU 1 have utilized one to three 8-inch hydraulic dredges, with considerably lower total production rates (i.e., less than 1,000 cy/day), than those targeted for OUs 2 to 5.

3.2.1.3 Navigation Access for Vessels Transiting the River

Portions of the Lower Fox River 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 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 dredging specifications will require use of submerged pipelines for high access and navigation areas, and navigation buoys to mark presence of anchor lines.

3.2.1.4 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 larger equipment. The predominant dredging equipment 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 (a.k.a horizontal auger dredges) are normally smaller dredges (less than 12-inch-diameter discharge) and typically work in water as shallow as 2 feet and as deep as 20 feet. Cutterhead dredges (under 12- to 14-inch-diameter discharge) can handle deeper depths with a range from 3 feet to 30 feet. Currently, an 8-inch cutterhead dredge is being used in OU 1 and is capable of working in 1.5-foot deep water. A 12-inch cutterhead dredge could be modified with additional floatation to achieve a 1.5-foot draft, but maneuverability would likely be limited as a result. Hydraulic cutterhead dredges may be preferred over augerhead dredges if the dredge cut is deep, although in the deepest of water even hydraulic cutterhead dredges can have limitations due to their maximum ladder lengths. The proposed dredge depths for OUs 2-5 of the Fox River are all less than 30 feet, thus a 12- to 14-inch cutterhead dredge would be applicable for the proposed work.

Mechanical dredges, or hybrid mechanical/hydraulic, may be used where dredging areas are concentrated or are erratic in shape. Clamshell dredges can handle deep digging (greater than 30 feet), while backhoe dredges normally require shallower operating depths. 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 successfully demonstrated on other projects and do not have the same minimum depth restrictions that barge-based transport has.

During more detailed RD, 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 types of equipment will be required to optimize the sediment removal.

3.2.1.5 Thickness of Sediments above the 1 ppm PCB RAL

The cut thickness that a dredge can attain will be a consideration when selecting equipment. The thickness of the required dredge cut (based on the thickness of sediment targeted for dredging) combined with the water depth will influence the type of dredge best suited for the removal as some dredges are more appropriate 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 types or sizes of dredging equipment will be required to optimize the sediment removal as various contamination thicknesses are expected.

3.2.1.6 Geotechnical Properties of Sediment

The geotechnical properties of the sediment being dredged will influence the selection of dredge equipment as well as the required operating parameters and the achievable production rate for that equipment. The sediment properties discussed in Section 3.1 are suitable for either mechanical or hydraulic dredge equipment. However, in some isolated areas the presence of hardpan (stiff clay, gravel, or bedrock) immediately underlying the contaminated sediments targeted for dredging may limit the effectiveness of most types of dredges at removing all of the contaminated sediment.

3.2.1.7 River Current Impact on Equipment

On average, the flow velocity in OU 3 and OU 4 is approximately 0.40 and 0.25 feet per second, respectively (see Section 2.2.4.2), with higher peak velocities occurring during seasonal runoffs or storm events. River currents are not always directed parallel 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 (e.g., associated with floods or large seiches), operations may even be temporarily halted. However, for the estimated river flow velocities during the anticipated construction work season, both hydraulic and mechanical dredging equipment should be capable of working without significant impact from river currents.

3.2.1.8 Presence of Significant Debris

Significant quantity of debris or large debris will impact the ability of different equipment to effectively dredge an area. For example, hydraulic equipment is typically not effective at excavating and transporting larger debris. Generally, a mechanical debris removal operation will be performed prior to initiating hydraulic dredging in an area of known debris. WDNR previously performed a side scan sonar survey to identify areas of significant debris. In addition, the NOAA (2002) navigation charts for the Fox River identify several potential debris zones, including sunken vessels. Additional surveys may be needed prior to construction to more precisely identify the location and characteristics of debris and/or historical artifacts within dredging areas.

3.2.1.9 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). However, dredging by any type of equipment is recognized to have some impact by its very nature. Thus operational best management practices (BMPs) will be included in the specifications to minimize potential impacts. These BMPs will focus on operations that the contractor will be required to take to ensure that the work is always under careful and tight control, and is predictable to the extent practicable.

3.2.1.10 Contaminant Resuspension

Sediment and contaminant resuspension can be partially controlled (depending on site conditions and operational characteristics) by strict quality control of the dredging operations and adherence to appropriate BMP procedures. These procedures will be clearly stated in the project specifications. Neither hydraulic dredge equipment nor mechanical dredge equipment is fully capable of preventing contaminant resuspension. While hydraulic dredges tend to be associated with lower resuspension (see Figure 3-10 discussed below), and there is not a significant enough difference between the two dredging methods to eliminate one from consideration due to contaminant resuspension.

3.2.1.11 Transport, Dewatering, and Disposal Considerations

The transport distances to disposal sites can impact the selection of the type of dredge and methodology for transporting the material to the designated disposal site. Typically, very long transport distances may be more suitable for barge and truck transport. As distances increase for hydraulic transport, additional pumping power is necessary to overcome friction losses in the slurry pipe. 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. Also, long transport distances over water can impact existing navigation and other river uses.

The availability and location of right-of-ways and easements could also limit the use of pipelines for hydraulic disposal. While WDNR has secured interim pipeline easements, the long-term viability of such easements still needs to be determined. Additional constraints include the presence of dams between OU 2, OU 3 and OU 4, where pipeline routing will be challenging. Furthermore, floating pipelines positioned in the river may impact both commercial and recreational navigation.

3.2.1.12 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 will 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 will be required for pipeline right-of-ways and for equipment access, where landside access is 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.

3.2.2 Production Rate Considerations

Many factors can affect the daily average production rate. The presence of debris, mechanical difficulty, ship traffic, and adverse weather are all factors that can slow production. During Year 2 of hydraulic dredging operations at SMU 56/57, production rates were required to be on the order of 833 cy/day for the project schedule to be met. As reported, however, production modifications and additional equipment were necessary to meet this rate, and the capability of the dewatering system was one of the rate-limiting factors identified shortly after production started. While the project was completed on schedule, production on many days was well below the target of 833 cy/day, while on rare occasions production approached a daily maximum of 1,600 cy/day. However, given that the size and type of equipment proposed for use on this project are significantly different from the size and type of equipment used for the SMU 56/57 project (two 12-inch-diameter swinging ladders vs. a single 10-inch-diameter horizontal auger), direct comparisons between the demonstration project and the ROD Remedy are not appropriate.

For the ROD Remedy, the production rate for hydraulic dredging will likely be limited by the capacity of the transport line and stabilization basin to handle the volume of slurry. It has been assumed for this BODR that up to two hydraulic dredges could potentially work simultaneously; however only one transport pipeline to the dewatering location (discussed further in Section 4) will be provided due to the large capital and operating costs associated with the line. In order to use two dredges on one transport line, a stabilization basin will be necessary to combine the flows from the dredges prior to pumping to the dewatering and disposal facility. If at any time only one of the dredges is operated (as would be the case in OU 2 and 3), a “make-up” water pump would be required to provide the additional flow necessary to maintain pipeline operation that would normally be provided by the second dredge). Operational difficulties associated with the operation of a dredging and transport system configured in this manner (i.e., two dredges pumping into a single pipeline, which does not appear to have been previously implemented on an environmental project of this scale within the U.S.) may affect production rates. Implementation uncertainties associated with this aspect of the ROD Remedy are discussed further in Sections 3.9 and 5.9.

For this project, a single 12-inch hydraulic dredge was assumed to have a flow rate of 5,000 gallons per minute (gpm), and a slurry concentration of approximately 6.1 percent solids by weight based on a review of the sediment properties and the range of dredge cut thicknesses. This results in a production rate of 2,400 in situ cy/day when efficiency (assumed at 48 percent “up-time”) is considered. For two dredges, the daily average removal is estimated to be approximately 4,800 cy/day (twice the rate for a single dredge). As previously discussed, work is not anticipated to be possible during winter months. In addition, a six-day per week schedule is envisioned to allow 1 day of maintenance to occur weekly during construction, as necessary. Given the logistical difficulties of routing two floating pipelines around the De Pere Dam, it has been assumed that only one dredge would operate in OUs 2 and 3 with additional flow provided by a water pump. Following completion

of dredging OU 3, two dredges would operate simultaneously in OUs 4 and 5. Based on these production rates, implementation of the ROD Remedy is estimated to require approximately 15 to 24 years of dredging (including construction of the staging facility, pipeline, and landfill), based on the dredge volumes discussed in Section 3.5, and considering operational uncertainties anticipated with the two-dredge system outlined above. This calculated construction duration is longer than that estimated in the 2003 ROD. However, the ROD assumed a longer construction season through burial of the 18-mile-long transport pipeline (although the costs of such burial were not included in the ROD cost estimate), along with higher production rates and efficiencies. Based on the initial design analyses completed for this BODR, summarized below, neither of these conditions was determined to be cost-effective or reasonably feasible.

Recent (2005) dredging experience in OU 1 and in the 1998/1999 Deposit N demonstration project revealed that dredge production is significantly reduced when air temperatures drop below freezing. Furthermore, when freezing temperatures are sustained for multiple days, dredging becomes technically infeasible due to equipment "freeze-up" and the development of surface ice on the river. These conditions typically occur in the region between November and May. Although, the available in-water construction season may vary from year to year, an average working window of approximately 6 months was identified as reasonable for BODR estimating purposes. Insulation of the dredge slurry pipelines through burial was initially considered, but such an option was determined to be impracticable and not cost-effective, especially considering that the pipeline will require rotation on a regular basis to prevent uneven wear, as discussed in Section 8.2.1.2.

Production output for each dredge was based upon a flow rate with multiple passes of lessening in-situ concentrations resulting in average concentrations of in situ sediments at 14 percent by volume. Preliminary confirmation of these production rate estimates was provided through discussions with experienced dredging contractors. Dredging operations, sequencing, and scheduling are discussed in more detail in Sections 3.9 and 6.

3.2.3 Equipment Selection to Remove Prospective TSCA Sediments

For removal of sediment potentially subject to TSCA disposal requirements (see Section 2.3), a mechanical dredge was identified as the cost-effective and appropriate equipment under the ROD Remedy. Its production is limited somewhat by the necessity to more precisely remove the sediments while minimizing the entrained water and the associated need for dewatering amendments (see Section 4). Some of the face heights (i.e. cut thickness) of the sediment potentially subject to TSCA disposal requirements are expected to be small, so a large bucket is not desirable; therefore, a 5 cubic yard clamshell environmental bucket is envisioned. Cycle times (3 minutes) used in the production estimates for the mechanical dredge reflect slower than typical cycles to account for precise placement of the bucket, lowering/raising of the bucket and cleanup passes to remove the material. Assuming the production parameters listed in Table 3-2, a daily production rate of approximately

1,175 cy is estimated for the mechanical dredging of sediments potentially subject to TSCA disposal requirements. Once removed, the sediment will be placed for transport within scow barges (or perhaps roll-off boxes on smaller barges) sized to suit the water depths and physical restraints in accessing the materials.

Table 3-2. Mechanical Dredge Production Rate for Sediments Potentially Subject to TSCA Disposal Requirements - ROD Remedy

Parameter	Unit	Value
Bucket Capacity	Cy	5
Bucket Load Efficiency	percent	70%
Cycle Time	minutes	3
Hours Per Shift	hours	12
Shifts Per Day	--	2
Working Hours Per Day	hours	24
Working Days per week	Days	6
Percent "Up Time"/Day	Percent	70%
Daily Production Rate	cy/day	1,176

Mechanical dredge operational time windows were the same as the 180 days estimated for the hydraulic dredge and the operational days of the week were similarly estimated as 6 days per week (154 operational days/year).

No TSCA level material was found in OU 3; therefore there were no impacts from transport of material past the De Pere dam. Hence, the removal efforts of the mechanical dredge were confined to OU 4.

The removal period for the volume of sediment potentially subject to TSCA disposal requirements will need to be sequenced with the dredging of overlying non-TSCA sediments. For example, within portions of the abandoned/reauthorized OU 4A navigation channel, relatively deeply buried (greater than 6 feet below mudline) sediments potentially requiring TSCA management will not be removed until the overlying non-TSCA sediments are dredged. Based on these considerations, prospective TSCA sediment removal will likely occur in stages over a time frame of approximately 8 to 10 years under the ROD Remedy, as discussed in more detail in Section 6.

3.3 Methodology for Developing and Optimizing Dredge Prism Design

When preparing an engineering design to dredge and dispose of sediment, a major component of the dredge plan design is to define the dredge prism. The dredge prism consists of a required dredge

prism and an allowable overdepth. The required dredge prism represents the elevation, grades, and horizontal extent that a dredging contractor will be required to remove during remedial action implementation, designed to remove PCB contaminated sediment with concentrations greater than the 1 ppm RAL. The allowable overdepth is a constant thickness of sediment below the required dredge prism that engineers typically allow and pay the contractor for to account for dredging equipment accuracy and tolerances. The dredge prism design (including overdredge) reflects the fact that it is not possible for any dredge to excavate to an exact surface; in order to achieve a required elevation or grade, the dredge ends up removing excess material below the required dredge prism.

The dredge prism is developed to take into account many criteria. The primary objective of the dredge prism is to ensure that the contaminated sediment that is required to be removed falls within the horizontal and vertical extent of the dredge prism to the extent practicable. While the dredge prism design attempts to account for all critical criteria, the design is subjective and relies on dredge prism design experience, best professional judgment, and the quality and accuracy of the information provided to the design team. Because the dredge prism design relies on multiple sets of data, the precision of each data set (e.g., bathymetry, neatline depth and extent as defined by geostatistical methods) affects the level of certainty that the dredge prism encompasses all the contaminated sediments.

A summary of the overall steps in designing a dredge prism include: define the "neatline" area and depth to be remediated; specify site and project design criteria; prepare the dredge prism; and potentially adjust the dredge prism based on cost versus benefit evaluations. Each of these primary steps is outlined below.

3.3.1 Define the Neatline Area

The "neatline" area, depth, and associated volume was initially defined horizontally and vertically by geostatistical interpretation (e.g., Full Indicator Kriging [FIK] at a 0.5 LOS) of the pre-design sediment and analytical data, collected in this case as described in the agency-approved SAP/QAPP, and Addenda Nos. 1 and 2. The neatline area is an idealized representation of the extent of sediments exceeding the 1 ppm RAL, and is always less than the actual area and volume of sediment that will be removed as part of construction operations (see Figure 2-23).

The initial delineation of the horizontal and vertical distribution of PCB concentrations that exceeded the 1 ppm RAL is discussed in Section 2.3. Additional field investigations as described in the SAP/QAPP and in Addendum No. 2 have been conducted to more precisely delineate the horizontal and vertical extent of sediments exceeding the 1 ppm RAL. These newer data will be folded into the ROD Remedy design during subsequent iterations of RD.

As discussed in Section 2.3, geostatistical analyses and cross-validation results indicate that a LOS of 0.5 will likely provide an optimum combination of maximum percent correct predictions and minimum overall bias, and this metric was used as the initial basis for delineating the neatline area. For OUs 3 and 4, FIK was used as the primary method for defining the neatline. Because of the relatively limited extent of sediments exceeding the RAL in OU 2, Thiessen polygons were used to define the neatline in this area of the site.

Within OU 4, scatterplots of predicted versus observed remediation depths for FIK identified a few isolated outliers with unusually high negative or positive biases. Thiessen polygons were superimposed over the kriged surface at these outlier locations to adjust the depth of contamination and improve the accuracy of the neatline surface. Ongoing geostatistical analyses (with new 2005 data) are being performed concurrently with dredge prism design analyses to refine the neatline, as appropriate.

3.3.2 Specify Site and Project Design Criteria

Once the initial neatline areas within OUs 2, 3, and 4 were defined, other design criteria were specified. These design criteria affect how the dredge prism is developed to encompass the neatline. The main objective in specifying design criteria for the dredge prism is to make sure that the dredge prism is constructable.

Dredging equipment accuracies and tolerances limit the ability of a contractor to precisely remove sediment to a specified neatline, since a dredge generally works in a two-dimensional plane, either by dredging across a constant dredge elevation or constant defined slope over a specific area. Since the neatline is typically a variable surface that undulates in three dimensions (often paralleling the bathymetry), the dredging contractor is not capable of only removing sediments to the neatline, but instead ends up removing additional (non-neatline) sediment. The quantity and extent of non-neatline sediment removed depends upon the complexity of the neatline area and how carefully the required dredge prism is designed to minimize non-neatline area removal. There is a trade-off between achieving minimized volumes and constructability when designing a dredge prism to remove the neatline area. Designing a dredge prism for lower volume removal (in excess of the neatline volume) generally translates to a less constructable dredge prism.

Key design criteria include:

- Slope Stability and Maximum Design Slope
- Infrastructure, Obstructions and Setbacks
- Allowable Overdepth
- Equipment Selection Considerations
- Dredge Cut Width
- Minimum Design Slope

3.3.2.1 Slope Stability and Maximum Design Slope

In order to ensure stable slopes within the dredge prism during the period of construction, available site geotechnical data have been analyzed to specify the stable design slope for dredge cuts. Cut slopes were modeled using infinite slope theory (Lambe and Whitman 1969) as described in Appendix A. Subsequent phases of the RD may include additional evaluations of slope stability using limit equilibrium slope stability software (e.g. Slide v5.01). The target factor of safety for these analyses was 1.5, based on the recommendations of the USACE (EM 1110-2-1902) for long-term conditions.

The sediment was modeled in the infinite slope analysis assuming undrained conditions, with engineering and strength parameters based on detailed evaluation of the vane shear test conducted during the RD investigations as well as the laboratory strength tests from undisturbed sediment samples. For a 10-foot high cut slope at 3 horizontal to 1 vertical (3H:1V) the factor of safety is greater than 2.0 (See Appendix A).

Based on these analyses, side slopes will be generally specified as 3H:1V for OUs 2 to 5. It should be noted that after the dredge has excavated material from a specified area, the adjacent uncut area (or new cut face) will stand at 3H:1V slope at least temporarily, but the slope may eventually fail (or slough) into the toe of cut at a stable slope shallower than 3H:1V. This design slope represents the slope expected to be stable during construction, which will allow accurate post-dredge verification that the required sediment inventory has been removed (i.e., based on bathymetric surveys).

Localized areas may require flatter slopes, depending on sediment characteristics, and other issues such as adjacent structures. For example, in order to maintain stable side slopes and shoreline infrastructure adjacent to the SMU 56/57 demonstration project, dredge cuts in that area were designed at 5H:1V (Foth & Van Dyke 2001). Flatter slopes may also be dictated by the dredge cuts required to match the target sediment removal elevation. Thus, the 3H:1V slope is considered a general criteria for the maximum steepness of a dredge cut, with areas of flatter slopes in the dredge prism applied where needed.

Within the dredge prism, if existing slopes are steeper than 3H:1V, the dredge prism will need to be adjusted. Without such an adjustment, the steep slope will be undermined and significant excess material will be removed.

3.3.2.2 Infrastructure, Obstructions and Setbacks

As was done during the second year of dredging at SMU 56/57 (Foth & Van Dyke et al. 2001), the dredge plan for the OU 2-5 project will contain necessary setbacks to avoid undermining existing structures and slopes during dredging activities. For cases where the extent of required cleanup extends into a bank that cannot 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 contingent capping) may also be considered in these localized situations to provide a more practicable remediation option. Such conditions will be evaluated on a case-by-case basis as part of the 30 and 60 Percent Design submittals using "as-built" information of existing structures and other shoreline survey information to be collected in spring 2006.

An area immediately southwest of the location of the SMU 56/57 demonstration project (represented by pre-design core location 4046-01) appears to be a particular candidate for nearshore capping, as sediments exceeding the 1 ppm RAL are present at depth in this area, well below the stable side slope and setback plane. At core location 4046-01, these side slope and setback considerations preclude dredging below approximately 6 feet beneath the existing mudline. However, more than 7.4 feet of sediments exceeding the 1 ppm RAL (a total contaminated thickness of more than 13.4 feet) will remain at this location following dredging, including sediments that are slightly above TSCA disposal screening levels (70 to 80 ppm). Sediment caps constructed in this side slope area will be designed to ensure permanent protection (see Section 5 and Figure 3-5).

Areas containing submerged structures such as pipelines, cables, or ruins may inhibit the use of a specific type of dredge in that area. In addition, rock and debris may also inhibit dredging and may require removal prior to dredging when feasible. In localized areas of excessive debris and obstructions, dredging may not be practicable based on implementability and engineering feasibility considerations, and the implementation of the contingent capping remedy may be considered.

The existing information on large infrastructure and overhead obstructions available at the time of this BODR is sufficient to show their general locations, but lacks the detailed structural information required to develop appropriate location-specific setbacks. Structural surveys and a historical record drawing search are still needed to develop these setbacks. These supplemental data are scheduled to be collected in Spring 2006, and will be integrated into the 30 Percent and/or 60 Percent Design submittals.

For purposes of the dredge volume estimates used in this BODR, slopes at the edge of the river were initially estimated as vertical cuts. However, adjustments during later phases of the design for in-water and/or upland structure or utility setbacks may result in shallower dredge cut slopes and/or a reduced dredge prism footprint. Therefore a lower volume of sediment may be removed around the perimeter of the dredge prism, and adjacent to in-river structures, similar to the SMU 56/57 dredging project in 2000 (Foth & Van Dyke et al. 2001). Furthermore, as discussed in Section 3.6.1, this BODR preliminarily identifies a nominal 75-foot-wide zone of potential shoreline capping along the river banks where greater than 1 to 2 feet of sediments exceeding the 1 ppm RAL was estimated at the river's edge. The remedy within this zone will be evaluated on a case-by-case basis during later stages of the design based on the results of the planned spring 2006 shoreline survey. These design

refinements will be integrated into the forthcoming 60 Percent Design. Table 3-3 presents a preliminary list of potential shoreline remedies, which will be considered during the 60 Percent Design.

Table 3-3. Potential Shoreline Remedial Design Considerations

Shoreline Condition	Potential Remedial Design ([a,b])
Shoreline deposits	If shoreline DOC < 2 ft, dredge with partial removal of uplands or cap if appropriate. Otherwise, cap along shoreline if dredging would impact stability.
Sheet pile wall	Site-specific review of wall design relative to potential dredge cut; cap along shoreline if dredging would impact stability.
Riprap or armored slope	Additional sampling in nearshore slope areas to refine extent of sediments > 1 ppm RAL; adjust dredging and capping plan accordingly.
Pile-supported wharf	Site-specific review to address impacts of dredging and/or capping
Floating dock with guide piles	Site-specific review to address impacts of dredging and/or capping
Outfall	Site-specific review to address potential options including: dredge around outfall; cap above outfall; relocate outfall; and extend outfall through shoreline cap
Shoreline building	Cap or dredge along shoreline depending on stability evaluation.
Shoreline or in-river bridge support	Cap along shoreline with review of potential dragdown forces on support
Utility crossings	Dredge offset from utility location; prospective capping area
Boat launch/ramp	Potential options include armored cap and dredge/armored cap.

(a) Final remedial design for these areas to be determined as part of the 60 Percent Design based on the results of detailed shoreline surveys and associated engineering analyses.
(b) DOC = Depth of contamination, as determined through geostatistical modeling.

3.3.2.3 Allowable Overdepth

Allowable overdepth is defined as material typically dredged below the required dredge prism when dredging to the required design elevation. To ensure removal of all sediment above the required dredge prism, the contractor will typically dredge below the required dredge prism. This is due to equipment tolerances and the inability of even the most modern dredging equipment to cut an exactly flat surface. Allowable overdepth in environmental dredging projects may range from approximately 0.5 to 1.0 feet. For the initial dredge plan design, a 0.5-foot thickness was assumed in developing this BODR. Very careful vertical control and/or specialized dredging equipment will be necessary to maintain an overdepth of 0.5 feet. As previously stated, allowable overdepth was not calculated into the dredge volumes estimated in the 2003 ROD.

3.3.2.4 Equipment Selection Considerations

Equipment selection affects the dredge prism design in several ways. The main effects are on setting the standard dredge cut width and constructable design slopes.

Dredge Cut Widths. To design a constructable dredge prism, the area to be dredged needs to be subdivided into dredging lanes. These lanes represent a single pass by a given dredge, and the cut width is based on the equipment's swing capability. Efficient dredging is accomplished when lane width is less than or equal to the maximum dredge swing capability. Lengthening the dredging lanes also helps the dredger from having to reposition the dredge, increasing efficiency. While dredging lanes are used with both mechanical and hydraulic dredges, the concept is more importantly applied to hydraulic dredging. Conventional hydraulic dredges (as opposed to "swinging ladder" dredges) swing their entire dredge plant (i.e., dredge head, fixed ladder, and barge) from side to side in an arc pattern to dig either a constant elevation, or with the help of computer and real-time positioning software, a constant design slope. Mechanical dredges typically use a crane mounted on the floating barge and the crane is capable of self-swinging without swinging the barge to excavate a specific location. Because of the method in which a hydraulic dredge swings while advancing, not using set dredging lanes will require the hydraulic dredge to constantly reposition itself laterally, often resulting in significant impacts on production rates and efficiency.

For a 12-inch hydraulic dredge (which may be optimally suited for application to OUs 3 and 4 under the ROD Remedy), the maximum effective cut width is approximately 100 feet. However, the dredge prism design may often set a narrower dredge cut width (lane width) to avoid excessive overdredging beyond the neatline area. When the neatline area bottom surface (i.e., depth of contamination surface) significantly varies in elevation, a narrower dredge cut width will help to minimize the amount of overdredging, though doing so will also reduce both the constructability of the dredge prism and the efficiency of the dredge.

Based on the highly variable bathymetry and depth of contamination surface found in OUs 2 to 5, a typical dredge cut width (lane width) of 50 feet was considered in the initial development of dredge plans (i.e., for this BODR). This width may vary depending upon site conditions, but the general concept will be to keep long dredging lanes approximately 50 feet wide, with a minimum width of 25 feet due to equipment capability.

Minimum Design Slope. As previously discussed, the maximum stable slope has been determined to be 3H:1V, based on available geotechnical data. When designing the dredge prism, the engineer can specify a constant design slope for the dredging contractor to achieve over a specified area, rather than a constant elevation. By using a constant design slope, the amount of overdredging beyond the neatline can be minimized.

Specifying a very flat slope will likely achieve little additional benefit, since the contractor will likely go ahead and set a constant elevation over that area to simplify the dredge prism and improve its constructability. In consideration of these factors, the preliminary dredge plan design used a minimum design slope of 25H:1V. This slope was selected based on best professional judgment and anticipated capability of a hydraulic dredge to effectively cut a very flat slope. If the neatline area slopes at a flatter than 25H:1V slope, the dredge prism was designed using a constant elevation. If the neatline area slopes at a steeper than 25H:1V slope, the dredge prism used a constant design slope to help minimize dredge volume.

3.3.3 Designing the Dredge Prism

Once both the neatline and dredging design criteria were specified, as outlined above, the dredge prism was prepared. The area to be dredged was simplified to establish either a constant elevation or a constant slope (over a given area). The required dredge prism was set at or below the deepest point of contamination (i.e., the deepest point on the neatline bottom surface with an RAL exceedance at a specified significance level) within a given area and an allowable overdepth thickness selected based on equipment selection and other objectives. Therefore, the dredge plan design includes removal of variable amounts of non-neatline sediment (i.e., sediment that does not exceed the RAL). Based on past experience on other similar environmental dredging projects, the average thickness of non-neatline sediment removed (including allowable overdepth) typically can be as little as 1.0 feet to much greater than 1.0 feet, depending upon the complexity of the neatline area. While this condition will provide an additional contingency against leaving contaminated sediment in place, the resultant dredge plan must still be designed as accurately as possible in consideration of geostatistical performance metrics (i.e., maximizing percent correct predictions and minimizing overall bias). This could potentially require iterative adjustments to the neatline and dredge plan design.

The preliminary ROD Remedy dredge plans for OU 3 and OU 4 are presented in Figures 3-1(a-d) and 3-2(a-e), respectively. Example details of the dredge plan are provided in Figures 3-3 and Figure 3-4. Representative ROD Remedy dredge plan cross-sections are presented in Figure 3-5.

Considering the potentially significant increase in volume that can occur as a result of the design process (i.e., the need to remove non-neatline sediment as well as overdredging allowance; see Figure 2-23), the ROD Remedy preliminary dredge plan will effectively remove PCBs to a significance level lower than the geostatistically-based significance level of 0.5 used to develop the neatline surface (see Section 2.3). Example cross sections presented in Figure 3-5 indicate that the ROD Remedy preliminary dredge plan will frequently remove sediments vertically to a 0.3 or 0.4 level of significance. The design team will perform further cross-checks during subsequent RD on the final design surface to evaluate its overall performance and predictive accuracy at delineating and removing contaminated sediment. Two types of cross-checks will be performed for the 30 Percent Design submittal:

- Using updated FIK geostatistical methods (i.e., incorporating 2005 data and additional geostatistical modeling refinements), a table of significance levels versus remediation volumes will be prepared. A preliminary table has been prepared for OU 3 and OU 4 using the 2004 data, leading to the selection of a significance level of 0.5 as an initial design parameter (see Section 2.3). As discussed above, a more stringent significance level will be realized as a result of the increase in remediation volume by the design process. The actual significance level that corresponds to the depth of the design surface, including overdredge allowance, will be estimated and mapped in the 30 Percent Design submittal.
- The remediation depth resulting from the design process will be cross-checked against the observed depth of contamination in cores, and presented in plan view as the difference between observed depths and design depths. An overall bias for each operable unit or subunit (either high or low bias) will be calculated from these comparisons. The plan maps, to be provided as part of the 30 Percent Design submittal, will also identify any areas or features in the river that may be subject to consistent over or undercutting.

Based on the degree to which the design surface modifies the remedial action to result in more stringent significance levels, potentially involving removal of significant volumes of uncontaminated (less than 1 ppm) material, and the magnitude of bias that is measured on the resultant design surface, further adjustments and refinements of the original neatline model surface may be performed during the 30 Percent Design to optimize the dredge plan. Thus, the design process is likely to proceed in an iterative manner until an acceptable balance between level of significance and minimization of bias in the design surface is achieved.

Ultimately, the dredge prism is a subjective design that attempts to define an optimal balance of the many factors described above, such as: removal of contaminated sediment that exceeds the RAL, achieving the lowest cost to meet removal objectives, balancing dredge volumes versus constructability, and ensuring that the dredge prism does not adversely affect existing structures.

3.3.4 Iterative Refinements through the Remedial Design Process

As discussed above, development of the remedial design is an iterative process. As the design progresses to successive levels of completion, new information will be taken into account as it becomes available, and the design will be modified to reflect any changes informed by the latest information. Examples of the iterative design process include the modification of the dredge prism design based on a more detailed shoreline survey, and the incorporation of 2005 sediment chemistry data into the geostatistical analyses. As discussed in Section 2.3, the dredge plan design presented in this BODR provides an initial balancing of Type I and II errors. Subsequent refinements of the design will overlay level of significance estimates onto to the dredge plan (including overdredge allowances) to further optimize the design. These steps are expected to be completed as part of the 30 Percent Design submittal.

The RD effort will also optimize the balance between design conservatism, confirmation sampling, and contingency response actions. For example, a relatively conservative dredge plan design (e.g., based on an effective LOS of 0.3, including overdredge allowances) will achieve a higher level of statistical significance by removing a larger volume of sediment, but also a larger amount of clean sediment along with contaminated sediment, resulting in a longer and more costly remedial action. Post-dredge verification sampling will be performed to document this condition (see Section 7). However, the effectiveness of the remedial action can also be ensured with a less conservative dredge plan design (e.g., based on an effective LOS of 0.5), if post-dredge verification sampling and contingency response actions were to be implemented to remove undredged inventory, as appropriate. Section 7 of this BODR provides an initial conceptual post-construction monitoring plan developed through Workgroup discussions. Refinements as part of later phases of the RD will optimize the dredge plan (including overdredge allowances) and confirmation sampling plan associated with the remedy. Details of the confirmation sampling plan will be presented as part of the 60 Percent Design submittal.

3.3.5 Minimizing Volume vs Constructability – Cost/Benefit Assessments

A formal cost versus benefit evaluation is typically not performed when developing a dredge prism due to the difficulty in assigning relative value to dredge prism complexity. However, the general concept of cost versus benefit is fundamental to the design process. In general, a more complex dredge prism design results in a less constructable and less efficient dredging operation, but with less volume. Less efficiency results in a higher unit price to remove dredged sediment. A simplified dredge prism results in a more constructable and efficient dredging operation, but with an associated increase in volume. Higher efficiency results in a lower unit price to remove dredged sediment. (Dredge plan designs typically do not influence dredge residuals, which are controlled to a greater degree by site characteristics and operational factors; see Section 3.6.4 below.)

The primary reason to design a complex dredge prism is generally to minimize the total volume removed. When the unit price to transport and dispose of contaminated dredge sediment is high relative to the removal cost, it typically is more cost effective to minimize the dredge volume than to try to save costs by simplifying the dredge prism. This is the likely cost scenario for OUs 2 to 5. Theoretically, there is a perfect point on a cost curve where finding the optimum balance of minimizing the dredge volume versus simplifying the dredge prism could identify the minimum cost.

Another element of the cost-benefit evaluation is the use of post-dredge verification sampling to guide and refine the boundary of the dredge plan, particularly in the horizontal dimension where post-dredge residuals may be less of a potential confounding factor. The cost and time associated with such a verification sampling-based approach will need to be balanced against the possible cost savings associated with a potentially smaller dredge prism. Again, such evaluations will be refined as part of the 30 Percent Design submittal.

3.4 Dredge Prism Design for Sediments Potentially Subject to TSCA Disposal Requirements

As discussed in Section 2.4, PCB concentrations in some areas of OU 4 exceed 50 ppm and may become subject to TSCA-imposed management and disposal requirements. The Wayne Disposal Facility in Belleville, Michigan and the Peoria Disposal Company in Peoria, Illinois are currently the only disposal facilities located in USEPA Region 5 that are authorized to accept waste containing 50 ppm or greater concentrations of PCBs (commonly referred to as "TSCA-regulated material"). During remedial design, other landfills could potentially be authorized to accept TSCA-regulated material, and may also be considered. An initial dredge plan analysis was conducted for this BODR to determine the volume of sediments potentially subject to TSCA disposal requirements. Section 2.4 describes the methodology for making such a determination, and Figure 2-26 identifies the locations of sediments that may be subject to TSCA disposal requirements. Based on the preliminary dredge plans developed using Thiessen polygon analysis (see below), an estimated 170,000 to 210,000 cy of sediments may require TSCA management under the ROD Remedy. As discussed above, the upper range of sediment volumes potentially subject to TSCA disposal requirements (210,000 cy) was used in this BODR.

3.5 Dredge Volumes

3.5.1 Volume Estimates in the ROD

Preliminary dredge volumes (including sediments potentially subject to TSCA disposal requirements) were presented in the RODs (WDNR and USEPA 2003). An estimated 595,800 cy were calculated for removal from OU 3 (including an estimated 9,000 cy from Deposit DD in OU 2) and 6,080,000 cy were calculated for OU 4 (including an estimated 200,000 cy from OU 5). The ROD did not consider overdredging allowances in these volume calculations. These estimated volumes were refined during the BODR as the extent of required cleanup was more fully characterized by the 2004/2005 sediment chemistry data, and as the dredge prism was developed to accommodate design considerations and allowable overdepth.

3.5.2 Basis for Computing Volumes

WDNR provided the bathymetric survey used to create the basemap for the BODR. RETEC (2004) conducted the survey in 2003. The horizontal datum for this project was Wisconsin Transverse Mercator (WTM), NAD83 with a 1997 (WTM 83[97]) adjustment, converted to U.S. survey feet. The horizontal datum, the basis for the 1997 adjustment and associated efforts to establish and document the locations of ground control survey monuments are described by RETEC (2004). The vertical datum for this project is IGLD85 in U.S. survey feet. However, the RETEC survey was conducted in North American Vertical Datum (NAVD) 1988 and corrected to IGLD85.

Dredge volumes were calculated using AutoDesk's Land Development Desktop (LDD) software through AutoCAD. A three-dimensional surface was created in AutoCAD v. 2004 for both the existing bathymetry and the required dredge prism, accounting for design side slopes. These surfaces each consisted of a set of contiguous, non-overlapping triangles known as a triangulated irregular network (TIN). Using LDD, the volume between these two TINs was calculated to represent the required dredge volume. The allowable overdepth volume was computed by taking the area of the dredge prism boundary representing the top of the dredge cut, and multiplying that area by the 0.5-foot allowable overdepth. The required dredge volume plus the allowable overdepth volume equaled the total dredging volume.

3.5.3 Sediment Volume Estimates

The ROD Remedy volume estimates initially developed by WDNR and EPA (2003) and updated for this BODR as described above, are summarized in Table 3-4. Overall dredge volumes estimated in this BODR are approximately 13 percent higher than those estimated in the ROD. These total dredge volumes include sediment potentially subject to TSCA disposal requirements, which was estimated at approximately 210,000 cy, as discussed above. A preliminary dredge prism was developed for this BODR to delineate and separately remove the TSCA-regulated material from non-TSCA level sediment. Section 2.3.2 presents a comparison of the PCB mass estimated during the 2003 ROD and the PCB mass estimated for this BODR using the data collected during this RD.

Table 3-4. Summary of Dredge Volumes – ROD Remedy (in cubic yards)

Operable Unit	ROD [(a)]	BODR - ROD Remedy [(b)]
OU 2	9,000	81,000
OU 3	586,800	716,000
OU 4	6,080,000	6,762,000
Total Dredge Volume	6,675,800	7,559,000
Volume Potentially Subject to TSCA Disposal Requirements (Included in Total Above)	200,000	210,000

Notes:
(a) Volume reported from ROD (WDNR and USEPA 2003).
(b) Volume based on dredge prism design and calculated using AutoCAD LDD. Volume also includes 0.5 feet of allowable overdepth.

3.6 Potential Impacts from Dredging

The removal of dredged material from OUs 2 to 5 has the potential to impact the river and its surroundings adversely both during the work, and after work is complete. During dredging, construction operations can interfere with the daily use of the river as the dredging equipment will block portions of the river while work is being completed. As the dredging is performed, the potential exists for environmental impacts to the surrounding air, water column, and sediment. Once

the work has been completed, the removal of dredged material could potentially impact slopes and structures by eliminating some portion of lateral earth support for these features.

All of these types of impacts must be carefully considered in both the dredge prism design and the dredge plan development so that they are minimized to the maximum extent practical. The following section describes potential impacts, and methods for mitigation before, during, and after the work has been completed.

3.6.1 Slope and Structural Considerations

As the design progresses through more detailed iterations, the infrastructure and obstructions identified in the project area from bathymetric surveys, side-scan sonar surveys, sub-bottom profiling and site surveys will be superimposed onto the dredge prism. Shoreline structures and areas containing submerged features such as pipelines, cables, or ruins may limit 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 capping may be required. In addition to evaluating the WDNR (2003) side-scan sonar survey results, the contractor may elect to perform their own pre-construction debris surveys to identify any new obstructions prior to construction.

The existing information on shoreline and in-river structural features and overhead obstructions is sufficient in showing their locations, but lacks the structural information necessary to develop required setbacks. Structural surveys and an as-built record drawing search will be needed to determine setback requirements. This work is planned for the spring 2006. In addition, a survey of historical structures and/or artifacts will be conducted in accordance with the National Historic Preservation Act of 1966 (amended through 1992, 16 U.S.C. 470). The dredge plan will be modified as necessary to add setbacks where these obstructions or historical artifacts have been identified. For planning purposes, similar to OU 1 identified artifacts, setbacks of up to 50 feet are expected to be necessary where these obstructions have been identified.

Along the shoreline, slope setbacks may be necessary to prevent undermining the shoreline, or removing lateral earth support for shoreline structures. A detailed inventory of shoreline features will be developed as the design progresses, and modifications will be made to the dredge prism to provide slope setbacks as necessary. For preliminary dredge designs, a 75 foot offset from shoreline line was incorporated into the RD to prevent undermining of existing slopes by dredging (see Figures 3-1 and 3-2). In areas where greater than approximately 2 feet of sediments exceeding the 1 ppm RAL was identified within this shoreline zone (see Figures 2-18 and 2-19), shoreline capping was assumed necessary. Table 3-5 presents a preliminary estimate of the amount of shoreline capping necessary under the ROD Remedy to avoid slope stability impacts. The 60 Percent Design submittal will

include a location-specific review of shoreline stability and potential structural impacts and will evaluate the need for shoreline capping.

Table 3-5. Preliminary Estimate of Shoreline Capping Areas

Operable Unit	Estimated Shoreline Capping Area [(a)] (acres)
OU 2	0
OU 3	9
OU 4/5	58

(a) Shoreline capping may be necessary under the ROD Remedy in those areas where dredging will adversely impact the stability of existing slopes. Further RD engineering evaluations will include a location-specific review of these areas.

3.6.2 Navigation Considerations

Brown County indicates that approximately 200 commercial ships visit the Port of Green Bay annually (http://www.co.brown.wi.us/solid_waste/port/). In addition, recreational boaters use OUs 2 to 5 on a regular basis for pleasure boating, fishing, and water skiing. The contractor will be required to coordinate closely with the U.S. Coast Guard (USCG) to provide notification and updates about ongoing work, and the potential interference between the dredging work and the daily use of the river.

Vessel traffic along the river influences selection of equipment. An assessment of vessel traffic (volume and types of vessel) may require coordination with entities such as the USCG station in Green Bay, the Port of Green Bay, and the industries along OUs 2 to 5. In addition, lock records may be reviewed to provide a more complete representation of vessel traffic on the river.

3.6.3 Short-term Water Quality Considerations

This section provides a review of data collected during RD to evaluate the potential for short-term water quality impacts during dredging of OU 2 to 5 sediments. As described in the RD Work Plan (Shaw/Anchor 2004), the results of elutriate testing performed on representative sediments were used in conjunction with dredge plume models developed by the USACE (e.g., DREDGE), to simulate the dissipation and attenuation of the dredge plume through the mixing zone. These data, in turn, were used to identify the need for and/or scope of dredging BMPs beyond standard dredging operational controls (e.g., limiting cut depths to minimize slope failure) to control water quality impacts. Water quality will also be monitored directly during construction.

The process of dredging creates turbidity in the water column. The contractor will be required to meet all applicable water quality standards that will be specified as part of a 401 Water Quality Certification for the project or substantive equivalent. Operational BMPs and controls will be implemented to minimize the potential for deviations from water quality standards.

Turbidity impacts from dredging activities are short term in duration. The anticipated dredging methods include both mechanical and hydraulic dredging.

Resuspension of sediment during hydraulic dredging operations can result from either of the following actions:

- Disturbed sediments loosened by dredge head, but not effectively captured and removed
- Failure of cut slopes
- Propeller wash from boat/barge traffic
- Use of spuds

Resuspension of sediment during mechanical dredging operations can result from the above processes plus the following additional bucket-related actions:

- The bow wave effect from lowering the clamshell bucket
- Impact of the bucket with the bed
- Bucket closure and removal from the bed
- Spillage and sediment sloughing during retrieval up through the water column
- Spillage and gravitational leakage from the bucket during hoisting and swinging from water to the haul barge

In addition to sediment loss from the bucket during mechanical dredging, sediment loss from the haul barge may also occur when the barge load reaches and exceeds the barge capacity. To minimize this potential, barge overflow will not be permitted.

While some turbidity is expected to be generated during dredging, very little resuspension (turbidity) of the clean cover materials is expected to occur during placement due to the particle size of the material that will be placed. Turbidity monitoring during cover and capping activities will be performed as required by the project Water Quality Certification.

Chemical mobility tests on OU 2 to 5 sediments were conducted during the pre-design evaluation (Shaw/Anchor 2004) to assess potential water quality impacts during dredging, handling, and disposal of sediments. The test used to evaluate short-term water quality impacts during dredging is the Dredge Elutriate Test (DRET).

This section of the BODR provides an evaluation of the potential for water quality impacts during dredging actions. First, the results of the DRET were reviewed to evaluate impacts of dissolved constituent release to the water column that may result from dredging operations. Next, potential short-term water quality impacts generated by sediment resuspension during dredging were modeled using the DREDGE computer model developed by the USACE (Hayes and Je 2000). DREDGE uses

estimates of resuspension rates in conjunction with field parameters (water current, sediment settling velocities, etc.) to predict suspended sediment and chemical concentrations at the point of dredging and at points cross-stream and downstream.

In addition to PCBs, other chemicals of potential concern were also evaluated to assess the potential for short-term impacts resulting from construction of the remedial action in OUs 2 to 5. For example, the DRET included conventional parameters such as ammonia and biological oxygen demand (BOD), as well as metals that have the potential to dissolve into the water column under certain environmental conditions. As summarized in the RODs, metals of potential concern identified in OUs 2 to 5 are arsenic, lead, and mercury. In contrast to PCB distributions (see Section 2.3), bulk sediment metal concentrations appear to be more elevated in OU 3 compared to OU 4.

The results of these short-term water quality evaluations are used in this BODR to determine the need for and scope of BMPs, monitoring, and contingency response actions during conduct of the remedial action. BMPs recommended to ensure water quality protection are summarized in Section 7. A Construction Quality Assurance Plan (CQAP) to be developed as part of the 60 Percent Design submittal will provide details of water quality monitoring, BMPs, and contingency actions.

3.6.3.1 Conceptual Model

Dredging activities cause turbidity and resuspension of river sediments. Field studies have indicated that hydraulic cutterhead dredges and mechanical dredges employing environmental buckets and operational BMPs can usually minimize sediment resuspension to about 1 to 2 percent of the mass of sediment dredged (Hayes and Wu 2001, Anchor 2003). However, greater sediment resuspension rates often occur in areas with considerable debris, or when BMPs are not effectively implemented. A number of BMPs may be used to help control and minimize turbidity as necessary, including modifications and controls of dredging operational parameters such as cycle time and the depth of cut.

Sediment resuspended at the point of dredging creates a local turbidity plume that migrates and disperses down river. Through turbulent mixing and re-settling of sediment particles, the plume dissipates. Depending on site conditions, active mixing of the dredge turbidity plume and river water can rapidly ameliorate the effects of in-water construction activities. Consistent with the requirements of NR 102.05(3) and with the approved design for initial dredging operations in OU 1, the potential for water quality exceedances in the vicinity of the dredge will be minimized to the extent practicable, particularly to prevent acute toxicity to aquatic life. For initial dredging in OU 1, the mixing zone was not allowed to exceed 500 feet from the point of dredging.

When contaminated sediments are being dredged, chemicals attached to the sediments may interact with river water when the sediments are resuspended. Some portion of the chemical mass remains

attached to the sediment particles, and another portion detaches from the sediments and dissolves into solution. The amount of chemical that becomes solubilized during resuspension is an important process which affects the bioavailability of constituents and their potential toxicity in the water column. This process is measured directly in the DRET procedures.

3.6.3.2 Existing Water Quality Conditions

One of the key RAOs of the RODs is to "minimize the downstream movement of PCBs during implementation of the remedy." Assessments of water quality impacts that may be associated with the implementation of the remedial action are based in large part on comparison with existing water quality conditions in OUs 2 to 5. A large set of information on existing conditions has been compiled for the Lower Fox River by various agencies, respondent parties (primarily the Fox River Group, or FRG), and other investigators.

Summary statistics for recent (i.e., collected over the last ten years) water data are presented in Table 3-7. The characterization of recent water quality conditions was based on the following studies:

- 1994-1995 Lake Michigan Mass Balance Study (USEPA 2002 & 2004b)
- 1998 FRG Sediment, Surface Water, and Biota Surveys (Exponent 1999, BBL 1999 & 2002)
- 2000-2001 FRG Surface Water Survey (LTI 2002)

Water Quality Summary Statistics. The mean, standard deviation, and coefficient of variation of total suspended solids, and dissolved, particulate, and total PCB concentrations are summarized in Table 3-6. Mean total suspended solids (TSS) concentrations in the Lower Fox River range from 16 to 48 mg/L, with an overall mean in OUs 3 and 4 of approximately 35 mg/L. Mean total PCB concentrations currently range from less than 5 ng/L (or parts per trillion) above OU 1 in Lake Winnebago (Neenah and Menasha Channel) to 19 - 38 ng/L in OU 4. On average, the particulate fraction accounts for about two-thirds of the total water column PCB concentration, and the dissolved fraction accounts for the remainder.

Distribution of Water Column PCB Concentrations. Downstream trends in water column PCB concentrations in the Lower Fox River were characterized during a 2000-2001 monitoring program by the FRG, as shown in Figure 3-6 (LTI 2002). Inspection of this graph suggests downstream increases in PCB concentrations as the river flows through OUs 2 to 4 during both base flow and high flow events.

Seasonal Trends in PCB Concentrations. Three investigations are available which provide water quality monitoring data over the course of a year, allowing an assessment of seasonality:

1. The 1989-1990 Green Bay Mass Balance Study (GBMBS);

2. The 1994-1995 Lake Michigan Mass Balance Study (LMMBS); and
3. The 2000-2001 FRG study.

Seasonal trends in PCB concentrations observed at the mouth of the Fox River in these three investigations are shown on Figure 3-7.

The data presented in Figure 3-7 reveal a pronounced seasonality in PCB concentrations in the Lower Fox River during all three investigations. The highest concentrations typically occur during the warm weather months from April through October (when dredging will occur), and the lowest concentrations occur during the winter months of December through February, with March and November being transition months. Concentrations during winter are about an order of magnitude less than concentrations during the warm-weather dredging months. Temperature appears to be one of the key factors controlling the seasonality of water column PCB concentrations (LTI 2002), either through direct action (i.e. PCB solubility) or through more indirect mechanisms (i.e., by affecting biological productivity, bioturbation, methane production, dissolved organic carbon, etc.).

Seasonal Trends in PCB Loads. Estimated mean monthly PCB loads (concentration times flow in mass/day) at the mouth of the Lower Fox River are shown on Figure 3-8. Following the PCB concentrations, there is similarly a pronounced seasonality to PCB loads.

3.6.3.3 Water Quality Screening Criteria and ARARs

This section describes the water quality screening criteria and ARARs that were used to evaluate DRET results. Water quality criteria promulgated in Wisconsin state regulations (Chapter NR 105) are the primary benchmarks used to evaluate water quality effects at the point of dredging in the Lower Fox River. TSS is a key monitoring parameter for all dredging operations. The state water quality standard for TSS increases, which was applied to the OU 1 dredging operation (see Section 3.6.3.4), is no more than an 80 mg/L incremental increase above ambient conditions. Given a mean ambient TSS concentration in OU 3 and OU 4 of approximately 35 mg/L, TSS concentrations in the dredging area will need to be maintained below 115 mg/L.

Most of the metals criteria are dependent on the hardness of the receiving water, and criteria were calculated based on a mean hardness of 181 mg/L in the Lower Fox River. Metals criteria are expressed on a dissolved basis, as recommended by USEPA (2002) and as allowed in state regulations (NR 105.05[5] and 105.06[8]), to assess the bioavailable form of these constituents. This is especially important in a dredging application, since dredging induced turbidity due to resuspension of sediments can create short-term elevations of total metals concentrations that may not be bioavailable.

The State of Wisconsin has also promulgated water quality criteria for PCBs and other bioaccumulative chemicals based on the protection of human health from ingestion of fish and/or drinking water for a lifetime exposure of 70 years (NR 105.08[5] and 105.09[5]). Existing water column PCB concentrations in OUs 3 and 4 are presently well above these criteria (see Table 3-7 and Figure 3-7). As discussed in the RODs, a remedial action objective is to achieve these water quality criteria. Reduction of bioaccumulation risks will be carefully monitored in the decades following remediation according to the requirements of the Long Term Monitoring Plan (to be prepared as part of the 60 percent Design). For the purpose of construction monitoring, however, bioaccumulation-based criteria are not applicable because they are based on an exposure period (i.e., decades) which is not consistent with the short-term nature of remediation activities.

3.6.3.4 OU 1 2004 and OU 4 1999 Demonstration Projects

During 2004 dredging of Lower Fox River OU 1 (Little Lake Butte des Morts) a cutterhead style swinging ladder hydraulic dredge was used to remove approximately 17,000 cy of sediment. Surface water turbidity was continuously monitored at three locations, one upstream and two downstream of dredging activities. The upstream monitoring station was located 100 to 500 feet from dredging activities. The first downstream monitoring station was located 500 feet or less from dredging activities and the second monitoring station was located 1,000 feet or more downstream. Surface water samples were collected once daily adjacent to the real-time turbidity monitors to develop a correlation between turbidity and TSS.

In the event that downstream turbidity exceeded upstream turbidity by more than 80 nephelometric turbidity units (NTUs), and the resultant increase was determined to be attributable to the dredging operations, the dredging contractor was required to alter operations to bring the turbidity levels back to within the allowable range. The same set of monitoring requirements and the same turbidity increase threshold was used to monitor turbidity during placement of sand cover materials for the project.

The USGS, in cooperation with WDNR, collected water samples during the 1999 SMU 56/57 demonstration project (Steuer 2000). Results of these and other associated monitoring programs were used to characterize the magnitude of off-site PCB transport that occurred during the dredging action. The data indicated that horizontal auger cutterhead dredging of approximately 650 kilograms (kg) of PCBs from SMU 56/57 resulted in the following:

- Approximately 14.5 kg (2.2 percent) of the dredged PCBs were transported downstream. This estimate was based on water samples collected roughly 100 to 200 feet downstream of silt curtains deployed around the dredge. Much (roughly one-third) of the water column load increase was attributable to dissolved PCBs that partitioned into the water from resuspended sediments;

- Approximately 2.6 kg (0.3 percent) was volatilized to the atmosphere; and
- Approximately 0.1 kg (0.02 percent) returned to the river from the treated dewatering facility discharges.

These data are within the mid- to higher-range dredging transport rates reported in other similar environmental dredging investigations (see Sections 3.6.3 and 3.6.4).

The results of the OU 1 turbidity monitoring in 2004 demonstrated that there was no significant increase in turbidity or TSS during dredging and sand placement activities (CH2MHILL 2005).

3.6.3.5 Dredging Elutriate Test (DRET)

The interaction of riverbed sediments and river water during dredging-induced resuspension is evaluated using the DRET procedure. The DRET test is a laboratory simulation of water quality at the point of dredging, as described in the OU 2 to 5 RD Work Plan, SAP, and QAPP (Shaw/Anchor 2004). DRET test results are evaluated in the context of mixing and dispersion processes which attenuate concentrations during transport from the dredging site.

DRET tests were conducted on eight large-volume composite samples representing three areas in OU 3, four areas in OU 4, and one area in OU 5 at the river mouth. Each sample was a bulk mixture of five cores composited over the depth of sediments containing PCB concentrations above the RAL. One sample from the upstream reach of OU 3 (CM-301) was comprised of cores with PCB concentrations both above and below the RAL, and resulted in a bulk composite PCB concentration below the RAL. This sample was nevertheless analyzed to provide a lower bound of potential water quality effects during dredging.

Chemical analytical results for bulk sediment concentrations, which provide the input material for the DRET tests, are summarized in Table 3-7. Total PCB concentrations (Aroclor basis) in the bulk samples ranged from 0.12 to 37 ppm. Because low-level PCB concentrations in the elutriate water samples were analyzed using high-resolution congener methods (EPA Method 1668A), the bulk sediment samples were also analyzed for congeners to evaluate method comparability. A significant difference between the Aroclor and congener results was observed ($P<0.01$), with the total Aroclor result equal to approximately 55 percent of the total congener result, across the range of sample concentrations (Figure 3-10; $r^2 = 0.98$). This congener-to-Aroclor ratio was applied to the elutriate data to be consistent with the Aroclor-based measurements specified for this RD.

Table 3-7. Bulk Sediment Chemistry in Composite Samples Submitted for Chemical Mobility Testing

SAMPLE	TOC *percent*	Arsenic *ppm*	Cadmium *mg/kg*	Chromium *mg/kg*	Copper *mg/kg*	Lead *ppm*	Mercury *ppm*	Nickel *mg/kg*	Silver *mg/kg*	Zinc *mg/kg*	Tot PCBs Aroclor *ppm*	Tot PCBs Congener *ppm*
CM-301	6.5%	6.0	1.4	40	82	92	0.85	18	0.42	150	0.12	0.19
CM-302	8.5%	7.4	6.4	100	150	240	8.4	28	1.40	390	2.9	4.9
CM-303	4.6%	5.0	2.8	73	95	130	6.6	19	0.94	220	6.1	9.8
CM-401	9.2%	4.9	3.4	110	100	170	3.2	19	1.10	310	37	92
CM-402	5.9%	3.7	1.6	88	64	96	2.6	16	0.83	190	15	24
CM-403	5.7%	3.5	1.6	70	66	97	3.5	14	0.73	170	13	25
CM-404	6.5%	4.6	1.2	50	48	67	1.2	13	0.72	130	13	25
CM-501	3.8%	19	0.9	29	50	48	2.0	11	0.42	95	2.0	4.1

In addition to PCBs, other chemicals of potential concern identified in the RODs were also evaluated in the bulk sediments and DRET determinations, particularly metals that have the potential to dissolve into the water column under certain environmental conditions. As summarized in the RODs, metals of potential concern identified in OUs 2 to 5 are arsenic, lead, and mercury. Bulk concentrations of these metals were particularly elevated in OU 3 (Table 3-7).

DRET results are summarized in Table 3-8 and discussed below.

Table 3-8. Dredging Elutriate Test (DRET) Results

Conventional Water Quality Parameters

SAMPLE		TOC mg/L	pH s.u.	Temp C	DO mg/L	TSS mg/L	Turb NTU	NH4 mgN/L	BOD mg/L	Hard mg/L
CM-301	TOT	21	7.58	22.0	6.7	560	430	0.8	2	210
CM-301	DIS	9.4								
CM-302	TOT	48	8.03	22.2	7.2	370	370	1.1	2.9	190
CM-302	DIS	9.5								
CM-303	TOT	24	7.63	21.8	5.5	390	380	0.8	2.6	190
CM-303	DIS	9.6								
CM-401	TOT	24	7.73	21.8	6.8	420	350	0.9	3.3	180
CM-401	DIS	8.7								
CM-402	TOT	12	8.00	21.5	5.7	440	420	1.9	2	200
CM-402	DIS	12								
CM-402-D	TOT	51	8.02	21.5	6.0	380	400	2.1	2	210
CM-402-D	DIS	10								
CM-403	TOT	10	7.80	21.5	6.2	400	380	1.4	2	190
CM-403	DIS	12								
CM-404	TOT	6.8	7.98	21.5	6.6	370	340	1.5	2.8	200
CM-404	DIS	12								
CM-501	TOT	19	8.03	21.5	6.1	390	320	1.0	3.7	200
CM-501	DIS	11								

Toxic Water Quality Parameters

WDNR Acute:	340	7.3	926	27	166	710	2,215	8.9	198		1,400 (1)
WDNR Chronic:	152	3.3	185	19	39	370	246	--	199		61 (1)

SAMPLE		Arsenic ug/L	Cadmium ug/L	Chromium ug/L	Copper ug/L	Lead ug/L	Mercury ng/L	Nickel ug/L	Silver ug/L	Zinc ug/L	Tot PCBs Congener ng/L	Tot PCBs Aroclor(2) ng/L
CM-301	TOT	4.2	1.2	35	71	78	633	19	2.2	110	42	23
CM-301	DIS	2.3	<0.1	0.7	3	2	14	2	0.3	43	37	20
CM-302	TOT	4.0	2.3	40	54	78	**2,060**	14	3.4	100	1,361	749
CM-302	DIS	2.5	0.2	0.9	4	2	46	1	0.2	41	61	34
CM-303	TOT	3.2	1.8	44	55	84	**3,530**	13	1.5	110	6,000	**3,300**
CM-303	DIS	1.3	<0.1	0.8	3	2	55	1	0.2	34	315	173
CM-401	TOT	2.6	1.4	56	48	70	**1,450**	11	<1.2	110	31,024	**17,063**
CM-401	DIS	1.6	0.1	1.2	4	2	22	2	0.1	53	2,851	**1,568**
CM-402	TOT	4.1	1.5	69	57	72	**2,960**	15	<1.2	130	11,591	**6,375**
CM-402	DIS	1.2	<0.1	1.1	3	1	57	1	0.1	24	276	152
CM-403	TOT	2.7	1.2	56	50	72	**2,700**	14	<1.2	130	11,572	**6,365**
CM-403	DIS	1.2	<0.1	0.9	2	1	23	1	0.1	33	307	169
CM-404	TOT	3.8	1.3	44	40	54	**1,280**	12	<1.2	82	13,050	**7,178**
CM-404	DIS	1.5	<0.1	<0.6	4	1	10	1	0.4	44	486	267
CM-501	TOT	4.0	1.1	37	48	61	**3,050**	15	1.5	130	3,016	**1,659**
CM-501	DIS	1.4	<0.1	0.6	3	1	20	1	0.2	36	90	50

Notes:
TOT = Total; DIS = Dissolved
(1) from ORNL (1996); value reflects total PCB concentrations
(2) Total Aroclors estimated at 55 percent Total Congeners; see Figure 3-10
2,060 Denotes exceedance of acute water quality criteria in the DRET

Conventional Parameters. TSS is a key monitoring parameter during most dredging operations. The average TSS concentration in the DRET test results was approximately 400 mg/L (Table 3-8), and represents the anticipated water quality condition at the point of dredging. The mean ambient TSS concentration in OU 3 and OU 4 is approximately 35 mg/L. Therefore, to meet the criterion of no more than an 80 mg/L incremental increase above ambient conditions at the mixing zone boundary, an attenuation factor (combined dispersion and settling) of approximately 5-to-1 will be required in the near-field zone surrounding the dredge (see Section 3.6.3.6 below).

All ammonia concentrations in the DRET results were below state water quality criteria. Similarly, pH ranged from 7.6 to 8.0, well within state standards. Dissolved oxygen concentrations ranged from 5.5 to 7.2, also well within state standards. Because these criteria are predicted to meet state standards at the point of dredging, no mixing with ambient river water is necessary (Table 3-9).

Metals. All dissolved metals concentrations in the DRET results were below state acute and chronic water quality criteria. Because these criteria are predicted to meet state standards at the point of dredging, no mixing with ambient river water is necessary (Table 3-9).

PCBs. Sample CM-401, a composite sample comprised of sediment collected from upper OU 4A contained the highest total (17,000 ng/L) and dissolved (1,600 ng/L) PCB concentrations in the DRET test results (Table 3-9). This sample was collected in the southwest corner of the head of OU 4A in an area of near-surface PCB concentrations that exceeded possible TSCA management levels (Section 3.4). Total PCB concentrations in the DRET from this area exceeded the acute screening criterion by approximately 12-fold, although total PCB concentrations in a dredge turbidity plume are not a good indicator of water column toxicity. Again, greater attenuation will be required when dredging areas containing greater than 50 ppm PCBs, and may necessitate the implementation of additional BMPs in these areas to ensure water quality protection (see discussion below). Aside from sample CM-401, all other dissolved PCB concentrations were lower than the acute screening criteria and generally within a factor of 5 of the chronic criteria.

3.6.3.6 Resuspended Sediment Releases at Point of Dredging

As discussed above, resuspension of sediment at the point of dredging, whether hydraulic or mechanical, occurs through a variety of mechanisms and typically affects the entire depth of the water column. However, the degree of resuspended sediment release in the upper portion of the water column is typically higher for a mechanical dredge than for a hydraulic dredging. A hydraulic cutterhead dredge could release sediment to the water column if the cut face were oversteepened and then failed. A mechanical bucket will resuspend sediment in the water column during impact, closure, withdrawal, and lift to the haul barge. In addition to sediment losses from the bucket, losses could occur if the barge load reaches overflow conditions; however, barge overflow will not be permitted during the OU 2 to 5 remedial action.

DREDGE is a computer model included as part of Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) suite developed by the USACE to evaluate the transport of suspended sediment from dredging operations in two distinct areas, "near-field" and "far-field." The area in the immediate vicinity of the dredging operation (typically 30 to 60 feet downstream from the dredge) is the zone of the highest total suspended sediments. This area is termed the "near-field" and is dominated by mixing and currents induced by the dredging process. In the "far-field" zone, suspended sediment transport is controlled by advection, turbulent diffusion, and sedimentation. DREDGE utilizes a two-dimensional, vertically averaged transport model to analyze sediment transport and attenuation in the "far-field" area (Hayes and Je 2000).

Resuspension Rate. The resuspension rate is a measure of the rate at which sediment is released into the water column at the point of the dredging, usually expressed as a percentage of the sediments dredged. The resuspension rate, and hence the associated turbidity plume, is dependent on a number of factors including dredge equipment and operating procedures, site conditions, and sediment properties.

The calculation of the resuspension rate for the DREDGE model is based on a literature review of estimated sediment release rates (source strength), for hydraulic and mechanical dredges as derived from field measurements, case studies, and predictive techniques (e.g., see Hayes and Wu 2001, Anchor 2003). Although each dredging project is unique, based on monitoring results at similar environmental dredging projects, including the SMU 56/57 demonstration project, a 1 percent loss rate was selected for this BODR to model typical conditions for hydraulic and mechanical dredges as may be applied under the ROD Remedy, and a 3 percent rate was selected to model short-term maximum losses that may occur relatively infrequently during dredging. This will be expected in areas of excessive debris, which may increase resuspension. However, these more turbid conditions will be of relatively short duration, and "average" conditions will likely be much closer to the 1 percent loss rate. (A distinction is made here between the loss (resuspension) rate as it relates to water quality impacts from dredging discussed above and the 2 to 8 percent (by weight) dredge residuals discussed elsewhere in this BODR. The latter dredge residuals are defined as sediment loosened by the dredge head that are not effectively captured and fall back onto the dredged surface.)

DREDGE Model Input. Table 3-9 presents the resuspension rate and other input parameters used in the DREDGE model for the analysis of the TSS concentration at selected distances from the point of dredging. Modeling was completed for a range of field conditions, including "expected" site and operating conditions, and assumed "worst-case" scenario conditions (e.g., high resuspension rates, debris, shallow water depth, and high current velocities). Specifically, the following scenarios were modeled:

- Resuspension rates of 1 and 3 percent during dredging;
- Current velocities spanning an order of magnitude, from one half the average river velocity (0.17 fps) to five times the average river velocity (1.7 fps); and
- Average water depth of 10 feet, and worst-case water depth of 2 feet (TSS concentrations generally increase during dredging in shallow water).

In addition, the following input parameters were used:

- Horizontal and vertical diffusion coefficients were selected from the range of values recommended in the DREDGE model user's guide; the lowest (and therefore most conservative) horizontal diffusion coefficient was selected; the vertical diffusion coefficient was calibrated within the recommended range to match the TSS concentrations observed in DRET tests.
- An average sediment composition of silty sand/sandy silt, with 50 percent sand and 50 percent fines (D_{50} = 74 um). Of those fines, 20 percent are in the clay size fraction (< 5 um). This input composition is based on RD sediment grain size determinations in OUs 2 to 5 as discussed in Section 3.1.
- Suspended sediment settling velocity of 0.0037 m/s. This velocity was calculated by the model based on the input grain size distribution and Stokes Law.
- Sediment density of 445 kg/m^3, based on 2004 RD measurements (corrected for core compaction).
- Typical hydraulic dredge operational parameters based on 12-inch diameter cutterhead.

Table 3-9. DREDGE Model Input Values

	Input Value	Units	Data Source and Comments
Dredge Parameters			
Dredge Type	Hydraulic		As defined in this BODR (ROD and Optimized Remedies)
Cutterhead diameter	0.31	m	Typical hydraulic equipment and operations
Cutterhead length	0.86	m	Typical hydraulic equipment and operations
Thickness of cut	0.91	m	Typical hydraulic equipment and operations
Swing velocity at cutter	1	m/sec	Typical hydraulic equipment and operations
In-situ dry density	445	kg/m^3	Average OU 2 to 5 value, 2004 pre-design data
Near-field TSS Model			
Average Loss Rate	1	% loss	Literature Review (Anchor 2003)
Maximum Loss Rate	3	% loss	Literature Review (Anchor 2003)
Far-field TSS Models			
Kuo's Model			
Lateral diffusion coefficient	100,000	cm^2/s	Model recommended range, minimum value
Vertical diffusion coefficient	10	cm^2/s	Model recommended range, calibrated to DRET results
Settling velocity - Average	0.0037	m/s	Calculated by model based on particle size distribution
Site Characteristics			
Water depth – Min	0.61	m	Assumed minimum water depth (2 ft.)
Water depth - Avg	3.05	m	Average water depth in OU 2-5 (10 ft.)
Ambient Water Velocity - Min	0.050	m/s	One half average velocity
Ambient Water Velocity - Avg	0.101	m/s	Average velocity OU 3-4 (see BODR Section 2.2.4.2)
Ambient Water Velocity - Max	0.503	m/s	Five times average velocity
Mean particle size	74	um	Average OU 2 to 5 value, 2004 pre-design data
Fraction of particles < 74um	0.5	unitless	Average OU 2 to 5 value, 2004 pre-design data
Fraction of particles < 5um	0.2	unitless	Average OU 2 to 5 value, 2004 pre-design data
Specific gravity of sediment	2.41	g/cm^3	Average OU 2 to 5 value, 2004 pre-design data

DREDGE Model Results. For this BODR evaluation, the mixing zone boundary was assumed to be 500 feet from the point of dredging, consistent with compliance monitoring being implemented in OU 1. Results of the DREDGE model are presented in terms of TSS concentrations as a function of distance from the point of dredging, along the centerline of the turbidity plume. The water quality standard used to evaluate OU 1 dredging operations is the same standard assumed herein—no net increase in turbidity greater than 78 NTU (corresponding to 80 mg/L TSS) above ambient conditions at the mixing zone boundary. Note that the OU 1 project included a two-tiered monitoring approach whereby a lower-tier standard of 38 NTU for turbidity would prompt a formal assessment of dredging BMPs to avoid reaching the higher-tier standard of 78 NTU.

Modeling predictions of turbidity during the range of average and worst-case conditions is summarized in Table 3-10. This table presents the maximum source concentration at the point of dredging, and the distance at which the dredge-induced incremental TSS concentration decreases to below 80 mg/L, in compliance with the water quality standard. Note that the resuspension rate of 1 percent results in point-of-dredging TSS concentrations which are in good agreement with the results

of the DRET test (400 mg/L, on average), whereas the TSS concentrations predicted using a 3 percent resuspension rate are significantly higher.

Table 3-10. DREDGE Modeling Results

		Typical Case (1% Loss)			
		Source Strength (TSS in mg/L)		Distance (ft) to +80 mg/L	
River Current Velocity		2' Water Depth	10' Water Depth	2' Water Depth	10' Water Depth
Average / 2	0.17 ft/s	410	410	50	50
Average	0.33 ft/s	490	490	65	65
Average x 5	1.7 ft/s	560	560	100	100
		Worst Case (3% Loss)			
		Source Strength (TSS in mg/L)		Distance (ft) to +80 mg/L	
River Current Velocity		2' Water Depth	10' Water Depth	2' Water Depth	10' Water Depth
Average / 2	0.17 ft/s	1,140	1,240	80	80
Average	0.33 ft/s	1,470	1,470	115	115
Average x 5	1.7 ft/s	1,690	1,690	230	230

Under the various scenarios, including average and worst-case conditions, TSS is predicted to meet the water quality standard between 50 and 230 feet of the dredge. Thus, dredging operations should readily comply with the water quality standard well before the mixing zone boundary is reached at 500 feet downstream from the dredge. Water depth had a relatively minimal effect on the resultant TSS concentrations because of the low value assumed for the vertical dispersion coefficient. A small dispersion coefficient is a conservative assumption because it will limit mixing in the vertical direction.

It should be emphasized that these model results are only predictions of the possible turbidity that could be created during dredging, to help identify potential water quality concerns in advance of the in-water work, and to design dredging BMPs accordingly if issues are identified. Based on the DREDGE model predictions, throughout most of the OU 2 to 5 dredging area no additional BMPs beyond standard dredging operational controls (e.g., limiting cut depths to minimize slope failure) are likely to be needed to control water quality impacts. Based on the DRET results (see Section 3.6.3.5 above), additional BMPs may be needed when dredging limited areas of the site containing relatively elevated PCB concentrations (e.g., sediment potentially subject to TSCA disposal requirements; see Figure 2-24). Water quality during construction will be monitored directly using turbidity meters and appropriate water sampling techniques.

3.6.4 Dredge Residual Management

As discussed in Section 2.5.2, residual contamination is typically evaluated in surface sediments following the completion of remedial dredging activities. The presence of residual contaminants is 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.

3.6.4.1 Management Options

Two management approaches will be implemented to address this potential residual contamination:

1. Specifying appropriate BMPs during dredging to minimize 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 RD 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 RAL, additional dredging may be implemented to remove sufficient remaining contamination to achieve the SWAC. The ROD also provides for the placement of a residuals sand cover on dredged areas to reduce the surficial concentrations and achieve the SWAC.

3.6.4.2 Post-Dredge Residual Expectations

A variety of recently completed remedial dredging projects have demonstrated that dredge residuals are commonly spread both within dredged areas and off site. Site conditions, dredging equipment, and BMPs may all effect residual levels. A survey of recent projects demonstrates that residuals can be expected in all dredging projects to differing degrees, and can result in post-remediation contaminant exposure within and immediately beyond the dredge prism if not adequately addressed

(Desrosiers et al. 2005; Stern and Patmont 2005). Residuals can potentially result in post remediation surface concentrations that are similar to pre-remediation levels.

Using a mass balance-based measure of residuals from a series of well-documented dredging projects, realistic expectations of residuals can be used to plan how to anticipate and respond to dredge residuals. Stern and Patmont (2005) summarize detailed residuals measurements from the following project sites:

- Fox River, WI (Deposit N and SMU 56/57 pilot projects);
- Lavaca Bay, TX (pilot project);
- New Bedford Harbor, MA (pilot project);
- Reynolds Aluminum, NY;
- Hylebos Waterway (mouth & middle), WA;
- Middle Waterway, WA; and
- Duwamish/Diagonal, WA.

For these remedial projects, the amount of sediment loosened by the dredge head but not effectively captured, ranged from approximately 2 to 8 percent of the mass of sediment (or contaminant) dredged (after digging to the design grade and following removal of high spots). The median amount of dredge residuals remaining in these environmental dredging projects was approximately 5 percent of the mass of sediment/contaminant dredged (Desrosiers et al. 2005; Stern and Patmont 2005). Similar dredge residual amounts have been reported for mechanical and hydraulic dredging operations, and with or without the use of BMPs such as silt curtains. Similar dredge residuals are also indicated based on preliminary analysis of the 2005 OU 1 post-dredge sampling data. Dredge residuals appear to be particularly significant at sites with considerable debris and/or slopes, both of which occur in portions of OUs 2 to 5. On a mass basis, dredge residuals represent a greater amount of loss than attributable to resuspension (Figure 3-10; from Stern and Patmont 2005).

For the purposes of the BODR, a range of 2 to 8 percent of the mass of sediments and PCBs loosened by the dredge under the ROD Remedy was assumed to settle back within or immediately adjacent to the newly cut surface of dredge prism, and the concentration of residuals was assumed to be equal to the average concentration of the sediment dredged, as outlined above. Based on these assumptions and using the preliminary dredge plan design and RD sampling data described previously, the approximate range of the post-dredge SWAC in OUs 3 and 4 can be estimated. These calculations reveal that without dredge residual management, and assuming an average 5 percent mass loss during dredging, the estimated post-dredge SWAC will likely be approximately 0.57 ppm in OU 3 and 3.7 ppm in OU 4 at the completion of ROD Remedy dredging (see Table 5-7). (Based on the RD sampling data, the existing SWACs in OU 3 and 4 are 2.0 and 3.2 ppm, respectively.) The post-

dredge SWAC estimates, particularly within OU 4, are well above the ROD target of 0.25 ppm, and underscore the need for effective dredge residual management.

As discussed above, BMP controls will be developed as part of the remedial design specifications to minimize the magnitude of dredge residual contamination. These controls may include the use of precise positioning systems and real-time monitoring of the dredge head and bed elevation, along with other elements. However, as similar controls were also employed on many of the projects summarized by Stern and Patmont (2005), an expectation of less than the observed range of 2 to 8 percent residual mass may be unrealistic for the OU 2 to 5 ROD Remedy design. If dredging does not remove all areas above the 1 ppm RAL and also does not meet the SWAC in an OU, the ROD provides for the placement of a residuals sand cover on dredged areas to reduce surficial concentrations and achieve the SWAC. Preliminary evaluations of the RD data set suggest that approximately 60 to 65 percent of the OU 2 to 5 dredge areas will likely require a residuals sand cover, which equates to approximately 580,000 cy of sand cover material if a 6-inch layer is placed. Surface sediment monitoring following completion of remedial actions will be performed to more precisely evaluate the need for and location of post-dredge residual covers (see Section 7). Design of dredge residual covers and caps is addressed in Section 5 of this BODR.

3.6.5 Noise and Air Quality Considerations

Noise. Noise emanating from industrial operations and other activities is generally regulated at the local level. For OUs 2 to 5, PCB remediation activities will occur in both Brown and Outagamie counties. While Outagamie County currently does not have a noise control ordinance, in Brown County, noise control ordinances have been established at the county level and within the City of Green Bay. These ordinances, summarized below, will be used as guidelines in the design of remedial actions, consistent with ROD requirements.

Noise is regulated in the City of Green Bay under City Code Chapter 27, Subchapter II, Section 27.201, Regulation of Noise. Brown County regulates noise under County Code Chapter 39, Section 39.01, Regulation of Noise. A review of these two ordinances indicates that the noise control requirements are essentially the same. Assuming that dredging activities will occur in an area zoned industrial and the noise can be detected in an area zoned residential, both ordinances require that during daytime hours sound pressure levels be limited to 64 dBA on average, as measured in the residential areas. During nighttime hours, the noise levels must be reduced to 60 dBA on average. However, each of the ordinances has a list of exemptions. One of the exemptions is for noise generated during daytime hours at construction sites. The City and County may allow noise levels to exceed the specified levels outlined in the ordinances, as long as the sound levels are “minimized through proper equipment operations and maintenance” and only occur Monday through Saturday. Daytime hours are defined as being between 7:00 AM and 10:00 PM. However, the exemption can be extended to nighttime hours. The contractor’s remedial action work plans may need to

demonstrate how work within Brown County will meet the substantive requirements of any applicable ordinances (e.g. equipment modifications).

Air Quality. It is expected that air emissions could potentially occur at a site from certain dredging, dewatering, water treatment, transport or disposal activities. These activities could release certain quantities of particulate matter and/or PCBs. As part of planning for a dredging project, potential air emissions will need to be assessed after gathering information regarding the specific activities or design of the project. Under WDNR regulations, NR 406 for Construction Air Permits and NR 407 for Operation Air Permits, air permitting could be triggered if emissions of either particulate matter and/or PCBs are above certain levels. While these substantive requirements will normally need to be considered under the air permitting program, air permits will not need to be pursued due to the permit pre-emption under the CERCLA process.

Air emissions of PCBs are also regulated by the WDNR under NR 445 for control of state hazardous air pollutants. More specifically, air emissions of PCBs are required to meet substantive requirements of Table A to NR 445.07 for PCB emissions. Table A specifies certain emission rates in pounds per hour (lb/hr) that are dependent on the height of the emission point. The allowable emission rates for PCBs vary from 0.0269 lb/hr for stacks less than 25 feet to 0.811 lb/hr for stacks greater than 75 feet. These emission rates are specified to ensure ambient air concentrations do not exceed 12 µg/m3, as a 24-hour average. This limit was developed by the WDNR to protect the public against potential non-carcinogenic health effects.

Facilities are also required to meet substantive requirements for an annual PCB emission limit of 0.1 pounds per year (lb/yr). This limit was adopted by the WDNR to protect the public against potential carcinogenic health effects, based on risk estimation and modeling work done by EPA. If it is determined that operations exceed this level on a facility-wide basis, then the facility may need to apply Best Available Control Technology (BACT) to the emission source if emissions cannot be maintained below 0.1 lb/yr. As defined by the WDNR, BACT will be the maximum reduction practically achievable on a case-by-case basis taking into account energy, economic and environmental impacts and other costs related to the source. If it is determined that emissions are greater than 0.1 lb/yr, the facility may need to apply BACT.

Noise monitoring was not conducted during the demonstration projects or at OU 1 during 2004, as industry history on dredging projects had not indicated concerns regarding unacceptable noise levels. During initial (2004) remedial actions in OU 1, an adjacent neighbor complained of noise emanating from the air monitor pump at one of the air monitoring stations. This problem was remedied by insulating the housing around the air sampler motor to the satisfaction of the neighbor.

Air monitoring during the Deposit N demonstration project consisted of real-time monitoring for particulates on all four sides of the on-shore treatment facility where mechanical presses were operated and sediment loading occurred. Results showed no exceedances of the particulate threshold of 96 ug/cubic meter (Foth & Van Dyke 2001).

Air monitoring at Demonstration Project 56/57 in 1999, conducted by WDNR, consisted of sampling for PCBs at several locations both adjacent to and more distant from active sediment handling operations. Of the 326 samples collected, approximately 63 percent (204 samples) were associated with the dredging area, 10 percent (31 samples) with the landfill, 10 percent (34 samples) with more distant background areas, and 17 percent (57 samples) were considered to be quality control samples (WDNR 2000).

During the monitoring events, samples collected immediately adjacent to the active sediment handling areas had total PCB concentrations ranging from 0.0002 to 0.0797 ug/m^3. Off-site concentrations collected during the same time period ranged from <0.00010 to 0.0036 ug/m^3, indicating a rapid fall-off in concentrations as the distance from the source increased. Background or baseline concentrations obtained prior to the start of dredging activities ranged from 0.0003 to 0.0016 ug/m^3 total PCBs.

Elevated concentrations above baseline levels were primarily associated with monitors that were within about 200 to 250 feet of the sediment handling operations. Samples collected at monitors situated at distances beyond this range approached background levels. Three samplers were located near the landfill area. These samplers were established at distances ranging from 840 to 1,240 feet from the landfill site. All samples collected from these monitor locations had measured concentrations at or below background concentrations.

Air monitoring was also conducted at OU 1 during 2004. Four monitors were located around the sediment dewatering and load out pad with the closest monitor approximately 100 feet from the active operations. The monitors were operated continuously. Air samples were analyzed for ambient air PCB concentrations. Concentrations of PCBs in the air were not detected at any of the locations (Foth & Van Dyke 2005).

Specific air monitoring requirements, during OU 2 through OU 5 remedial actions, will be determined during subsequent design phases (as described in Section 7).

3.7 ROD Remedy Staging Area Requirements and Design

Based on the discussion above, the ROD Remedy will require an upland staging area(s) to offload debris, sediments potentially subject to TSCA disposal requirements, and stockpile clean cover sand for residuals management. Desanding operations will also take place at the site, as described in

Section 4 below, requiring sufficient space to contain desanding equipment and stockpile areas for the sand collected from the desanding operation. In addition, the upland staging area will be used by the contractor for equipment storage, and will also serve as the location for the field office.

The upland staging area will require water access and sufficient berthing depth and length to accommodate floating equipment used for the remedial action. Debris and sediments potentially subject to TSCA disposal requirements will be transported by barge to the staging area, and will be offloaded using mechanical equipment (e.g., land-based crane with rehandling bucket). Sand supply vessels (e.g., barges or bulk cargo ships) will also need sufficient water depth and berthing length along a dock to tie up and offload.

A suitable staging area will provide the contractor with the following features:

- Sufficient acreage of upland for stockpile, equipment storage, and transfer facilities (e.g surge basin and initial connection to the pipeline transporting the dredged sediment to the passive dewatering basin).
- Adequate accessibility for truck access to haul routes.
- Minimum of 600 feet of dock face to allow tie up of two barges, end-to-end or sand supply vessel and one barge.
- Approximately 15 to 19.5 feet of water depth to accommodate moderate draft vessels and the bulk cargo ships delivering import cap and cover materials.
- Surface area capable of supporting heavy equipment.
- Drainage collection system for discharge of water from desanding operations or stockpile runoff prior to treatment and/or discharge.

Review of potential staging areas in OU 3 and OU 4 indicates there are no current sites that fully meet all of these criteria. Therefore, staging area selection is dependent upon finding potential sites that could be practicably improved to accommodate operations. The critical criterion for the staging area is to have sufficient upland acreage for required operations and stockpiling. Other key criteria may be obtained by site improvements.

Within OU 3, there are no sites that meet even a majority of the key criteria, and there are relatively few properties currently available for potential improvements. Within OU 4, the former Shell Oil property adjacent to the GP West Mill, which was previously used for a similar purpose during the SMU 56/57 removal action project (Foth & Van Dyke 2001), has sufficient upland acreage and has been identified as the most promising of all locations in OU 3 and 4. This site was identified as the prospective upland staging location for purposes of the BODR. During subsequent design phases the RD team will continue to investigate other potential staging locations, including properties shown on Figure 2-2. While the Shell Property meets many of the key criteria, several site improvements will be needed as outlined below in order for this site to be used as the staging area for the ROD Remedy. (Similar improvements will also be needed under the Optimized Remedy; see Section 5.8.5). Further

discussion of sediment transport to the staging area of mechanically-dredged sediments potentially subject to TSCA disposal requirements and hydraulically-dredged non-TSCA sediments is provided in Sections 3.8 and 3.9, respectively.

The Shell Property currently has approximately 22 acres of useable upland space, which should be sufficient to accommodate most contractor operations on-site. The shoreline is approximately 750 feet in length, sufficient to berth several vessels/barges at the same time if the entire shoreline were utilized. However, only 500 feet of the shoreline is currently useable as a wharf without substantive improvements (see Section 5). There are existing roadways and good accessibility to transportation corridors. Much of the surface will likely not require significant improvements to support heavy equipment.

While water depths immediately offshore of the Shell Property are presently relatively shallow, ranging from 2 to 6 feet below the NOAA low water datum, implementation of the ROD Remedy dredge plan will deepen the river adjacent to the Property. This deepening is essential for use of the property as a staging facility. The dredging action will also result in removal of a considerable number of existing pilings in this area, which preclude navigation access to the shoreline. Pile removal and dredging actions, if sequenced relatively early during the remedial action, will provide at least 15 to 20 feet of water depth (i.e., roughly elevation 562 to 558 feet IGLD 85) in the area immediately adjacent to the Shell Property. A sheetpile wall constructed along the shoreline will further facilitate shoreside equipment access and safe/efficient transfer operations. Thus, the critical site improvements at the Shell Property include: initial dredging in front of the facility to construct a berthing facility, improvement of the shoreline with a sheetpile wall, and backfilling behind the sheetpile wall with appropriate fill material to provide a level site. Pending further design evaluation, suitable material for backfilling may be obtained through excavation of clean surficial soils on the adjacent uplands. Temporary depressions resulting from such upland excavations would subsequently be filled with sands segregated from the dredge material (see Section 4.3).

Installing the sheetpile wall along the shoreline (at the base of a 3H:1V slope that will extend from the top of the existing bank) to provide a berthing facility will involve filling and conversion to uplands of approximately 1 acre of OU 4. The total length of the sheetpile wall will be approximately 600 feet, 500 feet of which will be accessible for berthing along the face (Figure 3-11). The sheetpile wall will partially achieve the dock criteria outlined above. The shoreline will be extended out from the existing shoreline by approximately 80 feet to provide access for berthing, increasing the total available upland acreage to approximately 23 acres. The required backfill volume will be approximately 20,000 cy, assuming a final top of bank elevation of approximately 585 feet IGLD 85. The upland backfill could be provided by using a relatively small portion of the appropriate on-site fill material.

3.8 Sediment Handling – Sediments Potentially Subject to TSCA Disposal Requirements

As discussed in Section 3.2, an important design objective is to minimize the amount of entrained water and dewatering amendments that will need to be added to sediments potentially subject to TSCA disposal requirements. Addition of dewatering amendments in this situation will also obviate the need for relatively expensive mechanical dewatering and water treatment facilities that would not otherwise be required to address the comparatively small volume of sediments potentially subject to TSCA disposal requirements (estimated at 210,000 cy; see above). Thus, a mechanical dredge is envisioned under the ROD Remedy for removal of sediments that may require TSCA management. For deeply buried deposits, the hydraulic dredge will remove the lower concentration overburden, prior to removal using a mechanical dredge of higher-concentration sediments potentially subject to TSCA disposal requirements. The mechanical dredge will use an environmental bucket to excavate the sediment to prevent loss of sediment while being raised through the water column and to avoid re-dispersion of any sediment suspended in the entrained water.

Typical dredge operations of the mechanical bucket include draining of excess bucket water when the bucket clears the water surface such that the transported sediment has as little excess water as possible. However, based on the results of the DRET evaluations summarized in Section 3.6.3, this BODR assumes that no release of water from the bucket will be allowed. Instead, the design visualizes this sediment and water within the bucket being transferred directly into hopper barges or deck barges with roll-off containers moored alongside the dredge without any discharge into the river. Silt curtains will be deployed during dredging of sediments potentially subject to TSCA disposal requirements to provide further water quality protection.

When full, the barge will be transported and emptied at the shoreside mooring facility discussed in Section 3.7. In the emptying process, the sediment will be mechanically transferred to a shoreside separation and stabilization facility where the sediments will be segregated from the debris. Appropriate care will be taken during the transfer process to avoid any spillage. The sediment will be amended to stabilize the material for transport and to prevent release of water. The relatively small volume of residual water or water that leaches during amendment addition and blending will be collected for batch treatment. Treatment of the water will occur on-site and the treated (and monitored) water returned to the river. Remaining water in the barges will also be pumped from the barge into the batch water treatment system. Only treated water will be returned to the river.

It is envisioned that the amended sediment will not have any free water. The dewatered sediment will, however, retain some moisture content and will be transported to an authorized treatment or disposal facility in lined or watertight trucks that will be sealed for transport of the sediment.

Under the ROD Remedy, no hydraulic transport of materials potentially subject to TSCA disposal requirements is planned.

3.8.1 Potential Offloading Procedures

Excavated material potentially subject to TSCA disposal requirements will be transported over to the shore offloading facility at the Shell Property (see Section 3.7). The shore offloading facility will be constructed to allow the mooring of the filled barges. At the offloading facility, mechanical excavators equipped with clamshell or backhoe buckets will remove the material from the barges. Sediments potentially subject to TSCA disposal requirements will either be amended within the barge or will be placed into an upland system to separate large debris or particles and allow the addition of the amending material to the sediments. The amended material will be stockpiled in a lined facility while awaiting transport by truck to the ultimate disposal facility. Spillage of sediments at the barge-to-shore connection will be prevented by the use of catch ramps or basins such that material that is dropped will be retained within the system. The storage of the sediments ashore will be within a lined facility such that no sediment or water will be allowed to migrate outside the facility.

Roll-off containers on barges are an alternative to the use of hopper barges. They could be lifted off the barge and placed ashore for amending prior to transport. In this design, hopper barges were considered and used in the pricing scenarios and planning.

Open deck barges were considered but rejected for the transport and handling of higher-concentration sediments (i.e., materials potentially subject to TSCA disposal requirements) due to the elevated potential risk of spillage, erosion from rainfall or ice melt and the increased efforts to remove the sediments from the deck of the barge.

3.9 Sediment Handling - Non-TSCA Sediments

The ROD Remedy described in this BODR primarily utilizes hydraulic dredging for removal of approximately 7.3 million cy of non-TSCA sediment from OUs 2 to 5 (see Table 3-4; relatively small quantities of nearshore sediment in OUs 2 and 3 may be removed mechanically). A floating pipeline system from the dredge(s), with appropriate booster pump stations (positioned based on linear pumping distances), will transport the dredge slurry to the sand separation equipment located at the Shell Property staging area. Pipeline design considerations will be addressed during the 30 Percent design phase. Some limited barge transport is anticipated to assist in removal of large debris.

Once the sand and gravel fractions have been removed, the dredge slurry will be pumped into a temporary stabilization basin on the Shell Property in order to regulate the flows from two incoming sources (i.e., the two dredges) to one outgoing pipeline to the landfill. The sediment will be pumped from the stabilization basin on the Shell Property across the bottom of the Fox River (through a

submerged 18-inch diameter steel pipeline) to the first in a series of shore based booster pump stations. From this initial booster pump the desanded dredge slurry will then be transported to the NR 213 passive dewatering cells through approximately 100,000 linear feet of pipeline with a series of shore based (in-line) booster pumps. For purposes of this BODR, the pipeline is assumed to be constructed on the established pipeline right-of-way (Fox River Trail in Figure 2-2 a), to its terminus at the NR 213 passive dewatering cell(s). As discussed in Section 4, below, for purposes of this BODR, the NR 213 passive dewatering cells are assumed to be located in Brown County (Figure 2-2 b). Sediment disposal considerations are discussed in more detail in Section 4.

The pipeline system from the dredges to the staging area will need to be easily movable and adaptable to traffic flows from commercial and pleasure vessels. It also must be visible to prevent any accidents. When considering the makeup of the floating line, consideration was given to the type of material being excavated and transported. In general, a steel line would resist wear from sand and gravel better than plastic (HDPE). However, an HDPE floating pipeline would be more easily set up, winterized, and moved to allow vessel passage when necessary. In addition, the cost differential between HDPE and steel is significant, allowing for one to two replacements of the HDPE line at the same cost as a single steel line. Properly constructed HDPE floating pipelines are extremely durable and highly resilient to the ebb and flow of the Fox River currents. For these reasons, an HDPE line was selected for all floating pipelines within the river, with steel selected for the submerged pipeline across the river bottom from the Shell Property on the west side of the river (Figure 3-11) to the pipeline right-of-way on the east side. In addition, a steel line was selected for the 18-mile-long section of pipeline leading to the disposal facility,

Hydraulic dredging will occur in a general upstream to downstream sequence throughout the remedial action, with one 12-inch hydraulic cutterhead dredge initially working in OU 2 and OU 3. Once remedial actions in the upstream OUs are completed, a second 12-inch hydraulic cutterhead dredge will be mobilized to OU 4 and both dredges will work concurrently for the remainder of the project.

3.9.1 Hydraulically Removed Sediment Transport in OU 2

Under this BODR design, a single 12-inch hydraulic cutterhead dredge is envisioned for removal of approximately 81,000 cy of sediments in OU 2. The dredge will remove the sediment within the designed dredge prism and pump the material through a floating pipeline to a floating booster pump station located immediately upstream of the Little Rapids Dam (well beyond the area of turbulence created by water flowing over the dam weirs). A relatively short stretch of shore-based pipeline, attached to this initial floating booster station, will cross over the Little Rapids Dam at the point where the dam infrastructure ties directly into the shoreline. From here, the floating pipeline will transport the dredge slurry through the entire length of OU 3 to the DePere Dam where the dam crossing will consist of shore-based pipeline utilizing the Fox River Trail right-of-way on the east side of the river. It is envisioned that 2 floating booster pump stations will be required to transport

the material the entire length of OU 3 (i.e., from the downstream side of the Little Rapids Dam to the upstream side of the DePere Dam).

From the downstream side of the DePere Dam the floating pipeline will require 2 additional floating booster stations to transport the material to the sand separation facility at the Shell Property (see Section 4.3).

The floating booster stations will be either diesel or electric powered (determined during 30 Percent Design phase), approximately 600 horsepower, anchored on steel hull deck barges and equipped with automation for synchronization of all the boosters with the dredge pumping system.

Due to relatively shallow water conditions near some sections of shoreline in OU 2, these areas may require mechanical removal from shore. Hydraulic dredging will need to be carefully coordinated with mechanical dredging and debris removal operations. Specific designs in these nearshore areas will be developed as part of the 30 Percent Design submittal.

3.9.2 Hydraulically Removed Sediment Transport in OU 3

Under this BODR design, a single 12-inch hydraulic cutterhead dredge is envisioned for removal of approximately 716,000 cy of sediments in OU 3. A single dredge was chosen for OU 3 due to the narrow navigation channel and the boating hazard that would be caused by two dredges (and accompanying floating pipelines). The dredge will remove the sediment within the designed dredge prism and pump the material through a floating pipeline (with accompanying floating booster stations) to the same upstream DePere Dam crossing used for OU 2 sediments, as discussed above. From there, the material will be transported through a floating pipeline with 2 floating booster stations to the sand separation facility at the Shell Property.

Dredging in OU 3 will begin in the upstream sections of this reach, proceeding downstream towards the DePere Dam. Based on the linear pumping distance from the dredge to the DePere Dam, either one or two floating booster pump stations will be required to maintain the proper flow velocities. As the pumping distance decreases one of the two initial booster pumps will be removed.

Due to relatively shallow water conditions near some upstream shoreline sections in OU 3, these areas may require mechanical removal from shore. Hydraulic dredging will need to be carefully coordinated with mechanical dredging and debris removal operations. Specific designs in these nearshore areas will be developed as part of the 30 Percent Design submittal.

3.9.3 Hydraulically Removed Sediment Transport in OU 4

Under this BODR design, two 12-inch hydraulic cutterhead dredges are envisioned for removal of approximately 6,552,000 cy of non-TSCA sediment in OU 4, in addition to mechanical dredging of approximately 210,000 cy of sediments potentially subject to TSCA disposal requirements. Within prospective TSCA areas, hydraulic dredging will need to be carefully coordinated with mechanical dredging and debris removal operations. In certain areas of OU 4, the hydraulic dredge will initially remove the lower concentration overburden, prior to removal using a mechanical dredge of higher-concentration sediments potentially subject to TSCA disposal requirements (see Section 3.8 above). Following removal of sediments for prospective TSCA management, the hydraulic dredge may then complete a final pass of the area to remove all sediment within the designed dredge prism.

Hydraulically-dredged sediments in OU 4will be pumped through two separate (i.e., independent) floating pipelines, one from each dredge, with accompanying floating booster stations, directly to the sand separation facility at the Shell Property. Separate desanding facilities may potentially be required to efficiently accommodate OU 4 sediment production resulting from concurrent operation of the 2 dredges. As discussed in more detail in Section 4, the resultant desanded dredge slurry will then be pumped into one stabilization basin or consolidation tank for further pumping through a single shore-based pipeline to the NR 213 passive dewatering cell(s) in southern Brown County.

4. ROD REMEDY - SEDIMENT TRANSPORT & DISPOSAL

As summarized in Table 3-4, the ROD Remedy described in this BODR includes mechanical dredging of approximately 210,000 cy of sediments potentially subject to TSCA disposal requirements, and primarily hydraulic dredging of approximately 7.3 million cy of non-TSCA sediment from OUs 2 to 5 (relatively small quantities of nearshore sediment in OUs 2 and 3 may be removed mechanically). The non-TSCA sediment will be subject to desanding to the extent that beneficial uses are established for the resultant sand fraction with PCB concentrations less than 1 ppm. The total quantity of sand that could potentially be separated and beneficially used under the ROD Remedy is approximately 530,000 cy, as described in more detail below.

As discussed in the RODs, following desanding, the dredge slurry will be transported via pipeline to a NR 213 settling basin, where it will be passively dewatered. As discussed in Section 4.1.1, future RD will include an evaluation of need of a dewatering amendment to achieve 50 percent solids by weight necessary for landfill workability. Immediately following amendment (if necessary), the sediment will be moved by truck from the NR 213 settling basin to an adjacent NR 500 monofill facility for final disposal. Preliminary evaluations suggest that the addition of some form of amendment (e.g. quicklime or similar) at approximately 5 percent by weight on average may be necessary. If the ROD Remedy is ultimately selected for implementation (as opposed to the Optimized Remedy discussed in Section 5), future RD investigations will include bench-scale testing to further evaluate the amount of dewatering amendment needed.

Given the likelihood of needing the amendment to achieve 50 percent solids, the NR 500 landfill (monofill) was sized to accommodate the additional volume from the amendment. The evaluation of potential upland disposal facilities was then based on this likely disposal quantity. However, the additional cost of amending the sediment was not included in the cost estimate for the ROD Remedy, as discussed in Section 4.1.1.

The volume of dewatered sediment (including the assumed amendment) to be generated from the NR 213 settling basin is expected to occupy approximately 4.7 million cubic yards in a NR 500 monofill including a 15 percent contingency to account for variations in the in situ and dewatered percent solids (Table 4-1). Due to the large volume of sediment requiring disposal, and given capacity limitations of existing landfills (see below), it is likely that more than one NR 500 landfill will be required for the ROD Remedy.

An alternate design considered during the BODR (described and supported for general effectiveness in the Detailed Evaluation of Alternatives Report (RETEC 2003) ("DEA") was the concept of a "dewatering landfill" for both dewatering and disposal of the desanded material. The DEA estimated that an area of approximately 176 acres would be required to support a dewatering landfill. While

design enhancements could likely reduce the required footprint to handle the revised ROD Remedy estimate of PCB impacted sediments, the required footprint for a dewatering landfill would likely still exceed 100 acres. As presented in Table 4-9, only three potential landfill sites are within 20 miles of the Site. None of these sites has an available disposal footprint approaching 100 acres. Therefore, this concept was rejected for the ROD Remedy because of implementation issues with the larger disposal volumes. However, this concept is considered further in Section 5, as an alternative to mechanical dewatering and trucking for the Optimized Remedy.

Mechanically dredged sediments potentially subject to TSCA disposal requirements (210,0000 cy) will be amended on-shore at the staging facility as described in Section 3.8, and transported with trucks to an out of state landfill designated to receive TSCA material. An additional 20,000 cy of shallow, nearshore dredging areas in OU 2 and OU 3 will likely also be dredged mechanically from the shore, amended, and transported by truck to the landfill facility.

Section 4.1 will discuss how sediment characteristics affect remediation processes; including sand separation, transport, dewatering and disposal. Section 4.2 will discuss how sediment characteristics were used in choosing specific remediation processes and disposal locations.

4.1 Sediment Characteristics

The physical and chemical characteristics of the sediments within OUs 2 to 5 are generally described in Sections 2.2 and 2.3 of this BODR. Section 3.1 provides additional details regarding the geotechnical properties of the sediments targeted for removal under the ROD Remedy. These sediments generally consist of sand and silt sized particles.

Under the ROD Remedy, desanded sediments dredged from OUs 2 to 5 will be delivered via pipeline to an NR 213 dewatering basin. Generally, a percent solids content of 50 percent by weight has been associated with meeting the required strength requirements for disposal of Fox River sediments in local landfills. The relationship between strength and percent solids will need to be developed as sediment is dewatered to establish the required solids content necessary to reach the strength requirements.

Following hydraulic dredging and dewatering in the NR 213 settling basin, the sediment may require amendment to achieve the desired 50 percent solids, as discussed in more detail in Section 4.1.1. For the purposes of sizing the NR 500 (non-TSCA) monofill and subsequent potential disposal facility evaluations (see Section 4.2), the sediment removed from the NR 213 settling basin was assumed to require an average of 5 percent amendment by weight. However, the cost of the actual amendment was not included in this BODR. Based on this assumption, the amended sediment from OUs 2 to 5 will require approximately 4.7 million cy, or 5.6 million tons, of capacity in a NR 500 monofill (Table 4-1). Included in this total is approximately 15,000 cy (18,000 tons) of amended

mechanically-dredged nearshore sediment from OUs 2 and 3. These quantities also include a 15 percent contingency to account for variations in the in situ and dewatered percent solids.

The estimated 210,000 cubic yards of mechanically dredged sediments potentially subject to TSCA disposal requirements will be amended at a nearshore staging area (assumed to be the Shell Property; see Section 3.7 and Figure 3-11). It is assumed that an amendment material available at the time of construction (quicklime was assumed for this BODR) will be added by mechanical means and blended with the sediment to attain a minimum 50 percent solids content. The total volume of amended TSCA sediment for landfill disposal is estimated at 268,000 cy (321,000 tons; Table 4-1) including 15 percent contingency.

4.1.1 Sediment Transport

In developing the details of sediment transport and disposal, several geotechnical components had to be considered in the decision making process. Based upon the results of the 2004 and 2005 RD investigations (Sections 2.1.2 and 3.1), the sediments targeted for removal under the ROD Remedy consist mainly of sand and silt-sized particles (75 to 80 percent by weight), with the remaining percentage consisting mainly of clay (approximately 20 percent) and a trace to slight amount (less than 5 percent) of gravel, as discussed in Section 3.1. The sand and gravel comprise approximately 40 percent by weight of the OU 3 and OU 4 sediment samples within the ROD Remedy dredge prism.

As discussed in Appendix C, sediment PCBs in OUs 2 to 5 are largely adsorbed onto the fine-grained soil fractions of the sediment. The fine grained fraction is defined as the percent passing the No. 200 sieve (P200), or as referred to in this BODR, silt and clay. The coarse-grained sediments (+P200), referred to in this BODR as the sand/gravel fraction, is the material under consideration for beneficial use.

This property of the contaminants may allow for material segregation of the sediments such that the coarser (i.e., sandier), sediments can be separated from the finer particles that contain the bulk of the contaminants.

Sand Separation. Sand separation in this case includes a sand-washing process to ensure that the segregated sand will contain PCB concentrations less than 1 ppm, and thus will not have to be transported through the long pipeline system to the NR 213 facility. The entire sand/gravel fraction separated from the non-TSCA sediments (approximately 530,000 cy) may be available for beneficial use, subject to the specific beneficial use opportunities available at the time of the remedial action.

Another benefit of sand separation at the staging facility is that less wear is placed on the pipeline and the lifetime of the pipeline is extended. The angularity and sharpness of the coarse grained sediments of sand/gravel will otherwise cause wear on the transport pipeline and reduce the pipeline's lifetime.

Even following desanding, it is anticipated that the pipeline will have concentrated wear along its bottom, since the bulk of the sediment is expected to be transported through the lower section of the pipe. To avoid concentrated wear, the pipeline will be rolled ninety degrees perpendicular to its axis at the quarter periods of the pipeline use (i.e., at approximately 4 year intervals, with one fourth of the pipeline rolled every year following the end of the dredge period).

A steel pipeline of approximately 18-inch diameter will likely handle the production of the two 12-inch hydraulic cutterhead dredges. Steel was chosen over plastic high density polyethylene (HDPE) to avoid problems associated with damage from vandalism. To anchor the pipe for elevation changes and potential thrust forces, approximately 10 anchor sites are likely to be required.

Shore Pipeline and Boosters. The booster pump stations were sized to handle the horsepower needs when pumping average slurry concentrations as determined by the 2004/2005 sample analyses for those sediments targeted for removal under the ROD Remedy. Approximately 9 shore-based booster pump stations were estimated along the pipeline from the staging facility to the NR 213 dewatering basin. It is envisioned that there will be some reductions in horsepower needs (also resulting in fuel savings) during those periods when the composition of the slurry being pumped is lighter than the assumed average specific gravity..

Booster sites were not individually selected or designed for in this BODR, but were estimated and sized to occur at an average of 10,000 foot spacing, with an average terminal elevation change of 20 feet and capable of pumping the average material composition as determined in the 2004/2005 sampling. Shore – based booster stations will be electric powered, approximately 600 horsepower, housed in temporary buildings for noise and weather abatement and equipped with automation for synchronization of all the boosters with the dredge pumping system. All of the booster systems will need to be steady-state systems that maintain a relatively constant flow to optimize system control and to avoid any potential pipeline plugging.

Any pipeline plugging will require a shutdown of the pipeline, dewatering of the pipeline system and careful removal of the trapped sediments to avoid release of contaminants. Allowances were made in this BODR for the automation system to control the flows. Also, in order to prevent plugging of the line, the system will pump continually at 10,000 gpm independent of the dredge's input to assure that the line is cleared of any bed load of sediment prior to shutting down for any reason. This continuous pumping will be maintained by a makeup pump providing feed water at the shore for the constant flow operations. With this constant flow, the requirements on the dewatering NR 213 facility are higher than if pumping and shutting down occurred at various intervals. The dewatering system was configured to meet these flows and a return HDPE plastic pipeline of 30-inch diameter was chosen as the low pressure return line from the NR 213 facility to the river.

Associated with the pipeline will be numerous road, driveway or ditch crossings where the pipeline will have to be buried or encased. These special sites (estimated at approximately 50) will require additional focus and design since they will experience higher wear than the straight sections of pipeline and will not be readily capable of rolling to distribute the wear.

NR 213 Passive Dewatering. As defined in the RODs, passive dewatering of the sediment must occur in a NR 213 facility. Thus, under the ROD Remedy, dredged sediments will be transported by pipeline to a multi-celled NR 213 facility (e.g., in southern Brown County), whereby the sediments will deposit and the effluent water will be drained from the facility for treatment prior to return to the river. Whatever sand is not removed by the desanding or sand separation operation at the shoreside facility will be transported with the other sediment to the NR 213 facility. The sand will deposit faster than the lighter sediments and will be located closest to the point where the pipeline discharges into the facility. The facility was conceptually designed to handle the separation of materials and the retention of the finer sediments within the cells. The potential bulking of sediments and consolidation after draining were considered in the sizing of the cells. Once drained to the proper water content and amended as necessary (see Section 4.1.1.1), the dewatered sediment will be trucked to an adjacent NR 500 disposal facility.

4.1.1.1 Sediment Disposal

Under the ROD Remedy, sediments dredged as part of the OU 2 to 5 remedial action could be dewatered in an NR 213 settling basin (or at an onshore staging area, for the lesser quantity of sediments potentially subject to TSCA requirements, as described in Section 3.8) and then transported as a solid to a landfill facility. Alternatively, sediments may be transported as slurry and deposited in a dewatering landfill where passive dewatering will occur. Section 4.2 provides additional details regarding the selection of a disposal facility under the ROD Remedy.

If transported as a solid, the dewatered sediment will require certain strength characteristics prior to being placed in a landfill facility. The history on the Lower Fox River sediments to date indicates that a compressive strength of 0.4 tons per square foot (tsf) for the dewatered sediment will result in adequate strength to allow workability and compaction with low ground pressure bulldozers, and attainment of positive drainage slopes on the final surface. For the SMU 56/57 project during 2000, the 0.4 tsf strength was achieved and operational problems were minimized with filter cake that achieved 50 percent solids or greater from pressing with mechanical plate and frame presses (Foth & Van Dyke et al. 2001). The necessary strength and solids content (approximately 50 to 55 percent by weight) required for landfill workability was confirmed through recent discussions with the WDNR Solid Waste Division and local landfill operators.

Sediment dewatered passively in the NR 213 settling basin will also require strength characteristics corresponding to approximately 50 percent solids by weight prior to being placed in the NR 500

landfill facility. Based on the in situ solids content of the sediment targeted for dredging under the ROD Remedy (see Section 3.1), it is estimated that the NR 213 settling basin will result in an approximate average dewatered solids content of 43 percent. However, it is anticipated that dewatered solids content will vary from 40 to 50 percent across the NR 213 settling, depending on numerous factors including dewatering time, sand content, etc. In comparison, the DEA estimated that the passive dewatering in the NR 213 settling basin would result in dewatered sediment with approximately 40 percent solids by weight after 24 to 36 months of dewatering.

Therefore, at least some portion of the sediment will likely require amendment to reach 50 percent solids by weight before final disposal in the NR 500 landfill. For the purposes of sizing the NR 500 monofill and subsequent potential disposal site evaluations as part of this BODR, it was assumed that passive dewatering in the NR 213 would result in an average solids content of 43 percent by weight. Based on this assumption, an average of 5 percent quicklime addition by weight will likely be required to achieve the necessary 50 percent solids by weight as presented in Appendix A. It should be noted that as much as 10 percent or more amendment could be necessary for some portion of the sediment prior to disposal in the NR 500 landfill. However, given the cost implications associated with the use any significant quantity of amendment (for example if a 5 percent by weight were required, the ROD Remedy cost could increase by as much as $220 million), the ROD Remedy cost estimate included in Section 8 does not include the cost of such amendments. Future RD investigations will include bench-scale studies to refine the estimated amount of dewatering amendment that would likely be necessary if the NR 213 settling basin were utilized.

4.1.2 Water Quality Considerations at the Disposal Site

As discussed above, non-TSCA dredged material from OUs 2 to 5 will likely be placed in either a NR 213 settling basin or an NR 500 landfill. Both types of facilities will be constructed according to State regulations which specify a two-layer liner system consisting of two feet of compact clay overlain by asphalt pavement (settling basin) or four feet of compact clay overlain by a minimum 60-mil HDPE geomembrane (dewatering landfill), followed by a gravel underdrain layer. However, for certain sediments with limited leachability potential (see Section 4.1.2.5), such liner, underdrain, and cover requirements may not be necessary.

To aid in dewatering the dredged material, water will be decanted off the top of the basin and interstitial water will be collected from the bottom of the basin. Both of these effluent streams will be treated as necessary (most likely sand filtration and granular activated carbon polishing of the discharge, similar to the system used for the SMU 56/57 demonstration project) and returned to the Lower Fox River. The quality and quantity of the discharge will be controlled such that water quality criteria will be met at the mixing zone boundary.

Laboratory tests were conducted using USACE protocols to evaluate the quality of the decant water (using the Modified Elutriate Test [MET]) and the quality of the porewater collecting in the underdrains (using the Pancake Column Leaching Test [PCLT]). These tests were conducted using eight large-volume composite samples representing three areas in OU 3, four areas in OU 4, and one area in OU 5 at the river mouth. This section presents relevant surface water and groundwater screening criteria, the results of MET and PCLT tests, comparisons of those results with screening criteria, and implications regarding water treatment requirements for discharge to the Lower Fox River.

4.1.2.1 Conceptual Model

Dredged material will be placed in an approved facility for dewatering and ultimate disposal. The engineered liner system at the dewatering and/or disposal facility (as necessary) will effectively eliminate migration pathways to groundwater. However, groundwater monitoring wells will be positioned around the facility, as required by State regulations. The monitoring wells will be positioned to provide an early detection of leakage through the liner, in the unlikely event it will occur. To evaluate the chemical "strength" of the underdrain leachate relative to this migration pathway, PCLT results were compared to Wisconsin groundwater quality criteria.

Dredge elutriate water will be decanted from the top of the facility to maintain the highest level of clarity in the effluent. Currently, it is anticipated that the detention time of the settling/dewatering facility will be about 12 days. That is, the dredge slurry will be allowed to settle for almost two weeks before it is either returned to the river, following appropriate water treatment (e.g. sand and carbon filtration).

Decant water and underdrain water will be treated as needed and returned to the Lower Fox River through a temporary outfall structure (see below). The objective of the water treatment will be to meet acute water quality criteria/ARARs as close as practicable to the point of discharge to the river, but no more than 10 percent of the distance to the mixing zone boundary [NR 106.06(3)(b)], and to meet chronic water quality (or existing background) criteria/ARARs at the mixing zone boundary, in consideration of mixing and dispersion processes [NR 106.06(4)]. The water treatment system will include solids settling, and may including other physical/chemical treatment elements as needed. To evaluate the treatment requirements for the return flow, MET and PCLT results were compared to prospective discharge limits from state ARARs (assumed for the purposes of this BODR to be equivalent to limits currently specified in OU 1), including acute and chronic water quality criteria comparisons specific to the OU 2 to 5 conditions. These evaluations are summarized below.

4.1.2.2 Water Quality Screening Criteria and ARARs

This section describes the water quality screening criteria that were used to evaluate MET and PCLT results.

State of Wisconsin Surface Water Quality Criteria (Chapter NR 105). Acute and chronic aquatic life criteria as promulgated in Wisconsin state regulations were used to evaluate water quality effects at the point of discharge to the Lower Fox River for decant water and underdrain water from the dewatering facility. These criteria are described in Section 3.6.3.3. In contrast to the evaluation of in-water point-of-dredging effects which were based on dissolved and bioavailable concentrations, the evaluation of point-source discharges of dredged material elutriate and leachate were based on comparisons to water quality criteria expressed on a total recoverable basis. The total recoverable basis is more appropriate for designing water treatment options, including options which may preferentially treat particulate versus dissolved fractions, and for evaluating improvements in water quality which may be afforded by extended settling times.

OU 1 Effluent Discharge Limits. Effluent discharge limits currently in use in OU 1 to regulate discharges of treated dredging elutriate and leachate water may also be applicable to OUs 2 to 5. These discharge limits include the following:

- Total Suspended Solids (TSS) – 10 mg/L daily maximum, less than 5 mg/L monthly average
- Biological Oxygen Demand (BOD) – less than 10 mg/L
- Ammonia – less than 67 mg/L (dependent on pH and effluent flow rate)
- PCBs (as Aroclors) – less than 0.5 µg/L (500 ng/L)
- Potential Hydrogen (pH) – within a range of 6 to 9
- Mercury – less than 0.2 to 0.5 ng/L

NR 140 Groundwater Quality Standards. Leachate concentrations in the PCLT test were compared to Wisconsin Groundwater Quality Enforcement Standards [NR 140.10, Table 1], as discussed in Section 4.1.2.5. The Enforcement Standards are risk-based criteria to protect public health primarily from consumption (as drinking water) of groundwater resources. Comparison of PCLT leachate quality to NR 140 criteria was performed to determine whether groundwater impacts are possible in the unlikely event that a liner leak occurs at the dewatering/disposal facility, and to determine the most sensitive monitoring parameters for groundwater monitoring at the facility.

4.1.2.3 Characterization of Dredging Decant Water – MET Results

The modified elutriate test (MET) simulates the chemical quality of dredging elutriate water decanted from a dewatering facility after a specified period of settling. METs were conducted on the 8 composite sediment samples received from the Fox River (FR-CM-301, FR-CM-302, FR-CM-303, FR-CM-401, FR-CM-402, FR-CM-403, FR-CM-404, AND FR-CM-501). Slurries were prepared so

that the concentration was equal to 150 g dry sediment per liter, or an approximate 7:1 water to sediment ratio (by weight).

Each of the slurries was placed into the appropriate size glass container and mixed by aeration for 1 hour. The mixture was then allowed to settle for 24 hours. After the specified settling time, the supernatant was siphoned off. Portions of the supernatant were collected for total analysis, and portions were filtered through a 0.45 micrometer (µm) membrane filter and submitted for dissolved analysis. An unfiltered aliquot of the supernatant was also analyzed for pH, TSS, turbidity, temperature and dissolved oxygen (DO). MET results are presented in Table 4-2.

The MET results provide an indication of expected elutriate quality after one day of settling. The following general observations are evident from these data:

- In general, higher particulate and dissolved concentrations were observed for all water quality parameters in the MET compared to the DRET (see Section 3.6.3), because the MET was performed using a thicker slurry concentration and a prolonged settling time which provides for more contact between water and sediment phases.
- Relatively high TSS concentrations, ranging from 1,800 to 18,000 mg/L, remained in the elutriate after one day of settling.
- The elutriates contained relatively low oxygen concentrations and elevated oxygen demand, probably caused by the suspension of fine-grained organic material in the dredged sediments. BOD in nearly all of the elutriates (ranging from 8 to 29 mg/L) will exceed the OU 1 discharge limit (10 mg/L) after one day of settling. Dissolved oxygen in all of the elutriates (ranging from undetectable to 4.4 mg/L, and averaging 1 mg/L) was also depressed below the state water quality standard (5 mg/L). In addition, ammonia was slightly above the OU 1 discharge limit (67 mg/L) in two samples.
- Metals and PCB concentrations in the MET were dominated by the particulate phase and are primarily associated with suspended sediments. For most metals, the dissolved concentration accounted for only a few percent (2 to 4 percent) of the total concentration; for arsenic, the dissolved fraction was slightly higher (20 percent). For PCBs, the dissolved fraction was about 8 percent of the total.
- Dissolved mercury concentrations were above the Wisconsin acute criterion in four samples. Dissolved PCB concentrations in the MET samples exceeded the ORNL secondary acute benchmark of 1,400 ng/L (see Section 3.6.3.3) in the four samples from OU 4, but not in OU 3 or OU 5. No other dissolved constituents exceeded their respective acute criteria. These observations are important because extended settling during dewatering will decrease the particulate concentrations in the dredging elutriate, but may not significantly affect the dissolved concentrations.
- The highest concentrations of PCBs were observed in dredging elutriate from sample CM-401, collected at the southwest corner of the head of OU 4, in an area where some of the dredged material may be subject to TSCA disposal requirements. The highest concentrations of mercury were generally found in OU 3 (see Table 3-8).

MET Results Adjusted for Site Retention Time. As discussed above, the MET was performed using a 24-hour settling time in accordance with the standard test design of the USACE protocol. Since these tests were performed, however, additional design work has been completed on the dewatering facility, and current plans indicate a settling time of approximately 12 days will be achieved before elutriate water is decanted from the facility.

The results of column settling tests (CST) on Lower Fox River sediments showed a decrease in TSS concentrations from approximately 5,000 mg/L after one day of settling to approximately 100 mg/L after 12 days of settling, representing a 98 percent reduction in TSS concentrations. As a result, the 1-day MET concentrations were adjusted to an equivalent 12-day concentration by reducing the particulate fraction by 98 percent, and leaving the dissolved fraction at 100 percent of its value. After 12 days of settling, the dissolved fraction will become proportionately more significant, ranging from about 50 to 90 percent of the total concentration for chemical constituents.

Table 4-3 summarizes the predicted chemical characteristics of the decant water using the average MET concentrations summarized in Table 4-2. These concentrations were compared to OU 1 discharge limits and acute water quality criteria to determine whether the dredging elutriate could be discharged directly to the Lower Fox River, or alternatively, the degree of treatment that may be required prior to discharge. The highest reduction in concentration (10-fold reduction) will likely be required for TSS to meet the OU 1 discharge limit. An approximate 6-fold reduction will be required to meet the PCB discharge limit. The average total mercury concentration is about 20 percent higher than its acute water quality criterion. No other conventional parameters or metals exceeded their respective acute criteria.

Based on these data, a 10-fold reduction will likely be required to meet prospective discharge limits. The predicted concentrations of mercury in the decant water are also slightly above their acute criteria. Based on these results, an outfall design which optimizes mixing and/or water treatment may be needed. A quantitative analysis of the zone of initial dilution (ZID) was performed to help further define water treatment requirements, as described below.

Table 4-3. Average Chemical Characteristics of Dredged Material Elutriate (Decant Water)

Constituent	Units	Mean Total [1 Day][2]	Mean Diss. [1 Day]	Percent Diss. [1 Day]	Mean Total [12 Day][3]	Mean Diss. [12 Day][3]	Percent Diss. [12 Day]	OU 1 Dischg Lmt	Acute WQC[4]	Ratio to Acute WQC
Tot Susp Solids	mg/L	5,840			100			10		10
Tot Org Carbon	mg/L	180						--		
BOD	mg/L	21						10		
Ammonia (N)	mg/L	49						67		<1
Hardness	mg/L	925						--		
Arsenic	ug/L	42	8.6	20%	9.3	8.6	93%		340	<1
Cadmium	ug/l	25	0.6	2%	1.1	0.6	55%		8.6	<1
Chromium	ug/l	1,008	19	2%	39	19	49%		2,930	<1
Copper	ug/l	803	21	3%	37	21	57%		28	1.3
Lead	ug/L	1,300	21	2%	47	21	45%		190	<1
Mercury	ng/L	18	0.66	4%	1.0	0.66	65%		0.83	1.2
Nickel	ug/l	210	5.4	3%	9.5	5.4	57%		2,220	<1
Silver	ug/l	9	0.3	3%	0.5	0.3	63%		--	--
Zinc	ug/l	2,140	150	7%	190	150	79%		202	<1
PCB Congeners	ng/L	60	4.7	8%	5.8	4.7	81%	--		
PCB Aroclors(1)	ng/L	33	2.6	8%	3.2	2.6	81%	0.5		6.4

(1) Total Aroclors = 55% total congeners
(2) Weighted average concentration; OU4 = 90%, OU3 = 10%
(3) Estimated based on 98% reduction of particulate; 0% reduction of dissolved
(4) WQC = water quality criteria, expressed as "total recoverable" basis

4.1.2.4 Water Quality at Point of Discharge

Under the ROD Remedy, dredge decant water from an upland settling/dewatering basin likely sited in Brown County (see Section 4.4) will be piped back to OU 4, and will likely enter the river near the location where the slurry pipeline either enters or exits the river (i.e., on the west bank [near the staging area; Figure 3-11] or on the opposite east bank]). Treated decant water will be discharged back to the Lower Fox River through a submerged outfall pipe constructed specifically for this purpose. The river in this area varies in width between approximately 700 and 900 feet (depending on the specific outfall location selected). Relative to the NOAA low water datum in OU 4 of 576.5 feet IGLD 85, water depth in the prospective outfall area is approximately 25 feet. Preliminary design considerations indicate the outfall would be constructed of two 14-inch internal diameter (ID) ports, discharging near the bottom of the water column. These two ports will accommodate the discharge generated when two dredges are operating with a combined flow of approximately 10,000 gpm (14.4 MGD).

An evaluation of mixing and dispersion processes resulting from outfall discharge of dredging elutriate water into OU 4 (following settling of solids within the NR 213 dewatering basin) was performed using the Visual PLUMES model developed by USEPA (Frick et al. 2001). The three-dimensional mixing algorithm (UM3) was used to characterize site conditions and hydraulic processes, focusing on the zone of initial dilution (ZID) in the immediate vicinity of the outfall where

turbulent mixing occurs. The results of the mixing calculations were used to estimate water quality conditions at locations between the outfall and the edge of the prospective mixing zone. Dilution modeling was conducted in accordance with WDNR's *Mixing Zone Guidance for Chronic Toxicity and Zones of Initial Dilution*, 1992.

Mixing Zone Geometry and Points of Compliance. State discharge ARARs require that chronic water quality criteria (or background conditions, as appropriate for the receiving water characteristics) be achieved as practicable at the mixing zone boundary. For this BODR, the length of the mixing zone (in the downcurrent direction) was assumed to be 500 feet, consistent with state ARARs and with the size of the mixing zone currently being applied to remediation activities in OU 1.

State discharge ARARs also require that acute water quality criteria be achieved as practicable at the edge of the ZID [NR 106.06(2)(c)]. Although the ZID is often defined in hydraulic terms as that region where mixing processes are dominated by the momentum and velocity of the discharge ("near-field" processes), as opposed to that region where mixing is dominated by ambient river currents ("far field" processes, in which the plume is adrift in the river), there is a state regulatory definition of the horizontal extent of the ZID from the outfall that is an ARAR in this situation [NR 106.06(2)(c)]. The state definition of the ZID includes:

1. The ZID must extend no more than 10 percent of the distance to the mixing zone boundary (i.e., 10 percent of 500 feet = **50 feet**);

2. The ZID must extend no more than 5 times the local water depth (i.e., 5 * 25 feet = **125 feet**); and

3. The ZID must extend no more than 50 times the square root of the cross-sectional area of the outfall port (i.e., 50 * square root of 3.14 * 0.58^2 = **51 feet**).

Thus, based on these criteria, the ZID can extend no more than 50 feet from the outfall, and is limited in this case by the criteria specifying that the ZID must extend no more than 10 percent of the distance to the mixing zone boundary.

Model Input Parameters. Model input parameters are listed in Table 4-4. Several of the key parameters are described below:

- **Port Heights and Depths.** The two 14-inch ID outfall ports will be submerged in 25 feet of water and elevated 1 foot above the river bed. The ports will be spaced at least 20 feet apart and discharge will be oriented perpendicular to the flow of the river.
- **Design Flow and Velocity.** Per state ARARs, the design flow used to evaluate treatment requirements to ensure compliance with water quality criteria is the 7Q10 event (10-year minimum flow for a one-week period), which is 660 cfs for the Lower Fox River. Considering the cross-sectional area at the prospective outfall location, the 7Q10 flow roughly translates into a worst-case low river current velocity of 0.018 fps (excluding seiche

effects; note that the average measured current velocity in OU 4 is 0.26 fps; see Section 2.2.4.2).

- **Effluent Temperature.** If the effluent has a lower density relative to the receiving water, its buoyancy can influence mixing and dilution. In this situation, effluent density is primarily controlled by temperature. For this BODR, it was assumed that during detention in the settling pond, and conveyance in black HDPE pipe to the outfall in OU 4, the temperature of the effluent may be raised approximately one degree centigrade (2 degrees Fahrenheit) relative to the river water. It was also assumed that the river is well mixed from the surface to the bed.
- **Hydraulic Coefficients.** Default PLUMES values were used for this evaluation.

Table 4-4. Visual PLUMES (UM3) Modeling Input Values

Parameter	Input	Units	Reference/Notes
Outfall/ Effluent Conditions			
Number of Ports	2		During the operation of two dredges
Port Diameters	14	In	Preliminary engineering estimate
Distance Between Ports	20	Ft	Preliminary engineering estimate
Port Elevation	1.5	Ft	Elevation from river bottom to port centerlines (25 ft water depth)
Port Depth	23.5	Ft	Submerged depth from the surface to port centerlines
Vertical Angle	8	Deg	Ports are inclined slightly to prevent impingement of ZID on bottom
Horizontal Angle	90	Deg	Port discharges are perpendicular to river flow direction
Acute Mixing Zone Length	50	Ft	10% of distance to chronic mixing zone is determining factor
Chronic Mixing Zone Length	500	Ft	Assumed equal to OU 1 mixing zone
Effluent Flow	14.4	MGD	Two dredges - combined discharge rate of 10,000 gpm
Effluent Density	1000.0	Kg/m^3	Assume 2° F rise in river temperature during settling/transport
Effluent Concentration	100	Percent	Generic "tracer" concentration for dilution calculations
Ambient Conditions			
River Discharge	660	Cfs	Critical 7Q10 flow
Current Speed	0.018	ft/s	Current speed at specified cross-section under 7Q10 conditions
Ambient Density	1000.1	Kg/m^3	Approx. density at ambient river temperature (59 *F)
Density Stratification	None		Assume turbulent and well-mixed profile
Background Concentration	0	Percent	For generic dilution calculations

Model Results. Model results for the 14.2 MGD (10,000 gpm) discharge scenario are presented in Table 4-5 and on Figure 4-1. Dilution factors are presented for both plume average concentrations and maximum centerline concentrations. Key results include the following:

- An acute dilution factor of 10:1 or greater was achieved at the plume centerline at the ZID boundary (50 feet from the outfall) under the design discharge scenario.
- A chronic dilution factor of 20:1 was achieved at the plume centerline under the design discharge scenario. This amount of dilution was achieved at the end of the near-field turbulent zone, at a distance of approximately 100 feet from the outfall. Additional dilution will occur as a result of far-field processes between the edge of the near-field zone and the mixing zone boundary at 500 feet. However, the UM3 model developed by USEPA (Frick et al. 2001) is not currently linked to a far-field algorithm.

- Based on comparisons with the MET data and with predictions of decant water quality following solids settling in the NR 213 basin (Table 4-3), the dilution factors estimated using Visual PLUMES are more than adequate to meet all acute and chronic water quality criteria at their respective points of compliance.

More detailed designs of the return flow outfall and diffuser structure will be developed during subsequent design submittals.

Table 4-5. Visual Plumes (UM3) Model Results

	Dilution Factors				Near-field
Flow	**Acute - Avg**	**Acute - CL**	**Chronic - Avg**	**Chronic - CL**	**Distance[(a)]**
14.4 MGD	19	10	>30	>20	105 ft.

Notes:
(a) Chronic dilution factor includes near-field dilution only to specified distance in feet.
Additional far-field dilution expected, although UM3 not currently linked to far-field algorithm
CL = plume centerline

4.1.2.5 Characterization of Dredged Material Leachate Water – PCLT Results

The pancake column leaching test (PCLT) simulates the chemical quality of interstitial groundwater in the underdrain of a dredged material settling basin, or in groundwater emanating from a dredged material disposal facility.

PCLT Results. PCLT test results are presented in Table 4-6. These results characterize dredged material leachate quality over time. Time is measured in terms of pore elutions—the amount of time needed to fully purge the water-filled interstices of the sediment with new groundwater. Fifteen pore elutions were performed for each PCLT test; the last two digits of the sample ID correspond to the number of the pore elution. Alternate pore elutions were analyzed for PCBs (pore elutions 1, 3, 5, 7, 9, 11, 13, and 15) and metals (pore elutions 2, 4, 6, 8, 10, 12, 14).

The following general observations are evident from the PCLT data:

- The leachate in the PCLT test was oxygenated, with an average DO concentration of 6 mg/L. In many regional settings, groundwater DO levels are lower, and indicative of a more reducing geochemical environment which results in more limited metals mobility.
- PCB and mercury concentrations appear to generally decrease over time in most PCLT tests. However, time trends for other metals are not consistent. Lead concentrations appear to increase over time, and arsenic concentrations are relatively steady.
- With one exception, PCB concentrations in leachate were a small fraction of the OU 1 discharge limit (i.e., <5 to 25 percent of the limit). With the exception of sample FR-CM-401 collected from a region of upper OU 4A with sediments potentially subject to TSCA disposal

requirements, treatment of PCBs will not be necessary to return the leachate to the river. The low overall concentrations in leachate are indicative of the generally low mobility and hydrophobicity (i.e., tendency to adsorb to the sediments) of PCBs.

- Lead and PCBs were commonly above groundwater Enforcement Standards (ES) in the leachate samples. The highest lead concentrations were detected in leachate generated by sediment collected from are in the upper reaches of OU 3, averaging 230 and 370 ug/L in CM-301 and CM-302, respectively. These concentrations are up to approximately 20 times higher than the groundwater ES of 15 ug/L. The highest PCB concentrations were observed in samples collected from CM-401. As discussed in Section 2.4, sediments dredged from within the CM-401 area are targeted for separate disposal under TSCA. Excluding CM-401, peak PCB concentrations in the PCLT ranged from approximately 30 to 130 ng/L, or approximately 1 to 4 times the groundwater ES. Based on these data, lead and PCBs appear to be good "sentinel" constituents for groundwater monitoring around the dewatering/disposal facility.

Based on the PCLT results, and specifically based on comparison of PCLT leachate quality to NR 140 criteria, some but not all of the sediments targeted for dredging under the ROD Remedy have the potential to result in a groundwater quality impact if a release from the dewatering/disposal facility to groundwater were to occur. For most of the prospective upland dewatering and/or disposal facilities described in Section 4.2, however, engineered liner system already included as part of facility designs will effectively eliminate migration pathways to groundwater. At such facilities, groundwater monitoring wells will also be positioned around the facility, as required by State regulations. The monitoring wells will be positioned to provide an early detection of leakage through the liner, in the unlikely event it occurs.

For certain sediments with limited leachability potential based on the PCLT determinations, such liner, underdrain, and cover requirements may not be necessary to provide protection of water quality. For example, sediments that may be dredged from parts of the OU 4B navigation channel contain relatively low bulk sediment and leachate concentrations, such that leachate collection and/or groundwater protection systems may not be necessary for these materials. Subsequent remedial design submittals may identify additional disposal options for sediments with limited leachability potential.

4.2 Potential Upland Disposal Facilities

The Feasibility Study (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 a dewatering landfill concept. As discussed previously, a dewatering landfill is different from the combination of a NR 213 settling basin and separate landfill, in that sediments may be transported as slurry and deposited directly in a dewatering landfill, where passive dewatering will occur in place through final closure. The ROD for OUs 3, 4, and 5 selected a NR 213 dewatering basin followed by permanent disposal in an NR 500 landfill as the remedy for sediment dewatering

and disposal (see Figure 4-2). This ROD option included conveyance of the dredge slurry via a pipeline to a site within Brown County. The DEA Report (RETEC 2003) supported the general effectiveness of the ROD Remedy as well as the alternative of a dewatering landfill concept. The findings of these previous studies were based on a total in-situ dredge volume in OU 3 and 4 of approximately 6.7 million cubic yards without direct consideration of beneficial use.

As previously mentioned, the dewatering landfill design was considered during the BODR for both dewatering and disposal of desanded material. Based on initial engineering analyses, this concept was ultimately rejected for the ROD Remedy because of implementation issues and lack of cost-effectiveness resulting from the relatively large disposal volumes involved in this scenario. However, the dewatering landfill concept is explored further in Section 5, as an alternative to mechanical dewatering and trucking for the Optimized Remedy (due primarily to smaller disposal volumes).

The CERCLA RD Work Plan for OUs 2 to 5 (Shaw and Anchor 2004) describes the design phases, tasks and sequencing necessary to complete the RD in these OUs, including exploring appropriate practicable design alternatives, where appropriate. This BODR provides an evaluation of potential disposal facilities in proximity to OUs 2 to 5 that could provide dewatering and/or permanent disposal of the ROD Remedy sediment volume.

A process to screen and evaluate potential upland dewatering and disposal alternatives was described in the CERCLA RD Work Plan (Sections 2.7, 3.2 and 4.1). The first step in the process was an initial inventory of potential disposal facilities. Next, a set of threshold criteria were developed and applied to the potential sites to identify those dewatering and disposal options that clearly would not meet the needs of the project. The intent of the threshold evaluation was to eliminate sites from the more rigorous implementability evaluation (third screening step) if they clearly did not meet the threshold screening criteria. Following the implementability evaluation, modifying criteria were applied to the remaining alternatives, taking into account a variety of stakeholder and socio-political criteria that may affect the viability of a given alternative. Additional stakeholder interaction is necessary to fully evaluate the remaining dewatering and disposal alternatives, after going through the screening process described above. These discussions will continue as described in Section 9.

4.2.1 Initial Screen of Disposal Alternatives – Step 1

The process of identifying potential upland sediment disposal sites, and simultaneously identifying locations that could include an NR 213 passive dewatering basin(s), was initiated by first looking at currently operating disposal facilities within a 60 mile radius of the centroid of the sediment source, which was identified as RM 3.5 in OU 4. A distance of 60 miles was considered to be a reasonable maximum distance for truck transport of dewatered sediments. The initial source of this information was the WDNR 2003 Municipal and Industrial Landfill Tonnage Capacity Report available on the WDNR website at: www.dnr.state.wi.us/org/aw/wm/solid/landfill/2003Tonnage.

Proposed solid waste facilities within the same search area were also considered in the initial inventory of sites. Proposed facilities were defined as those with some or all permitting efforts previously performed, or currently underway.

Only existing or proposed facilities were considered in this evaluation due to the timeframe required to site new landfills in the state of Wisconsin. The landfill siting process typically requires 5 to 7 years, which would significantly delay the start of dredging in OUs 2 to 5.

An initial site inventory was discussed with the WDNR Solid Waste program staff during October 2004. Input from the WDNR led to refinement of the initial inventory as presented in Figure 4-3 and Table 4-7. The information summarized in Table 4-7 shows that 23 existing or proposed solid waste disposal facilities are present within the 60 mile radius of RM 3.5 in OU 4. Existing or proposed landfill sites were also considered as potential locations for NR 213 settling basins, a component of the ROD Remedy. Locations within 20 miles of the centroid of river mile 3.5 in OU 4 and in close proximity to the proposed pipeline corridor were also considered, in addition to existing or proposed disposal sites, since the NR 213 facility is temporary and the permitting process should be shorter than for an NR 500 landfill. Twenty miles was selected as the maximum distance due to the economics of pipeline transport beyond that distance given the timeframe for the project.

The size requirement for a NR 213 settling basin is significant in order to accommodate dewatering of more than 7.3 million cy of sediment (in situ volume; Table 4-1). The general process used to estimate sediment dewatering characteristics and associated disposal volumes and tonnages is presented in Appendix A. Both settling characteristics and storage capacity were evaluated. Based on analyses presented in Appendix A, the NR 213 settling basin area requirement is approximately 272 acres, assuming a maximum 6 foot sediment storage height at the basin outlet. Including buffer areas around the settling basin, the total property requirement to accommodate a NR 213 settling basin for the ROD Remedy is approximately 380 acres, given the above design constraints. The design of an NR 213 dewatering basin could possibly be optimized during later stages of design to fit within a slightly smaller footprint.

Additionally, disposal sites for PCB impacted sediments classified as TSCA material were inventoried. The two existing sites closest to OUs 2 to 5 are EQ Wayne Disposal in Bellevile, MI and Peoria Disposal Company in Peoria, IL. These sites are also included in Table 4-7. There are currently no disposal sites in Wisconsin licensed to receive PCB impacted sediments greater than or equal to 50 ppm. It is possible that disposal site(s) in Wisconsin could be permitted in the future to accept sediments potentially subject to TSCA disposal requirements. If this alternative becomes available in the future, it will also be evaluated at that time.

Glass Furnace Technology (GFT), developed by Minergy Corporation, has been proposed for vitrification of the Fox River PCB-contaminated sediment material. The GFT was tested on a pilot-scale for the melter and a bench scale for the dryers, as part of an EPA Superfund Innovative Technology Evaluation (SITE) demonstration in August of 2001. Capital and operating costs for commercial scale GFT facilities were provided by Minergy in March 2005, based on varying estimates of sediment volume and project duration. These costs were evaluated and compared with currently-available upland disposal estimates. Details of the Minergy cost comparison are presented in Appendix B. Based on this comparative evaluation, it was determined that the "large-quantity" vitrification concept is substantially more expensive than conventional landfill disposal. Evaluation continued on a proposed concept of a "small-quantity", co-located facility (built next to the existing Minergy paper-sludge processing facility in Neenah, WI) for vitrification of TSCA-regulated material only. The Remedial Design Team, in conjunction with Minergy, WDNR and EPA, evaluated the feasibility and cost-effectiveness of GFT for vitrification of TSCA-regulated material as part of the ongoing OU2 to 5 RD. Based on initial engineering analyses, the GFT process is not likely to be cost-effective (see Appendix B), and was not carried forward into further design evaluations

4.2.2 Threshold Criteria - Step 2

A straightforward method was used to narrow down the list of potentially suitable NR 213 settling basin and NR 500 disposal sites within the 60 mile radius for further evaluation. The primary threshold criterion for the NR 500 sites was disposal capacity. General siting and permitting issues associated with each site were also evaluated at this stage.

A threshold was set at a minimum of 1 million cy of capacity available for NR 500 disposal in 2008 (identified as the earliest possible starting date for dredging activities in OUs 2 to 5). This threshold also considered both currently permitted capacity and proposed capacity that could conceivably be brought on-line by 2010, which may be a more realistic date for full-scale sediment disposal. The 1 million cy threshold was set as a minimum volume to justify permitting and related issues associated with disposal at any one site, realizing that multiple sites could be used to dispose to handle the entire ROD Remedy volume.

The sites meeting the threshold criteria are listed in Table 4-8. It was determined that 14 potential NR 500 disposal sites met the threshold 1 million cy capacity. These 14 sites were then evaluated against the additional threshold criteria, as shown in Table 4-8.

To collect additional threshold screening information, NR 500 disposal sites that met the 1 million cy capacity were either sent a letter or contacted by telephone requesting additional information. Several weeks after the initial contact, the site owners were contacted again and asked a series of questions. The results of those discussions were used to fill in the remaining information in Table 4-8. Those owners that were receptive to further discussions then attended individual meetings to further discuss

potential use of their facility for disposal. These facilities were then moved into the next level of screening as discussed in the next section. Facility owners that showed no interest were sent a letter confirming their position and were not evaluated further. Copies of the letters are included in the disposal site evaluation documentation (Foth & Van Dyke 2006).

The NR 500 disposal sites that emerged from the threshold evaluation were:

- Brown County South
- Brown County VandeHey
- Onyx Hickory Meadows

It should be noted that there are no existing or proposed landfill sites within 20 miles of river mile 3.5 that have a 380-acre tract of land available for both an NR 213 settling basin and a NR 500 disposal site. Since an NR 213 settling basin is a temporary land use, siting such a facility, separate from an NR 500 landfill, on a large tract of land in Brown County not currently in the landfill siting process, may be possible within the project time constraints. If appropriate, other land tracts such as Brown County's land holdings south of the Brown County South landfill site may be further evaluated for this purpose in subsequent design phases.

The threshold evaluation for potential TSCA sites was simplified by looking at the two closest sites that are currently licensed to accept TSCA material. The EQ Wayne Disposal Site in Belleville, MI and Peoria Disposal Company site in Peoria, Illinois. The other threshold criteria applied to the TSCA sites was capacity to accept up to 300,000 cy of material. Both facilities have adequate capacity to handle 300,000 cy of sediments potentially subject to TSCA disposal requirements.

4.2.3 Implementability Criteria – Step 3

Implementability criteria were then established to further screen the potential NR 500 landfill disposal sites that emerged from the threshold evaluation. The three sites that emerged from the threshold evaluation are as follows:

- Brown County South – Wet Process Residue site (Figure 4-4)
- Brown County VandeHey – MSW site (Figure 4-5) or Wet Process site (Figure 4-6), but not both, and
- Onyx Hickory Meadows Landfill (Figure 4-7).

The implementability criteria include specific permitting and siting issues as listed on Table 4-8. Implementability criteria include whether the facility's Local Agreement addressed receipt of PCB impacted sediments, and additional siting and permitting issues that would need to be completed prior to having a licensed facility available for disposal. The above three sites remained on the list for

further evaluation following implementability screening. Figure 4-8 shows the locations of the three potential landfill sites relative to the OU 2 to 5 project location. In addition to these sites, the RD will continue to consider other sites that either have accepted dredged sediments or may be able to do so during the project period, such as the Bayport Material Disposal Facility.

Brown County South Wet Process Residue Site

The Brown County South Wet Process Residue site is located approximately 14 miles from the OU 4 centroid (RM 3.5; Figure 4-4). The site is adjacent to the site previously permitted for disposal of municipal solid waste (MSW). (The MSW site is part of the Tri-County solid waste agreement between Brown, Outagamie and Winnebago counties and was therefore screened out of consideration in the previous evaluation stage.) The wet process residue site at the Brown County South site currently has a completed Feasibility Determination from WDNR, but the Plan of Operation required for permitting of the facility has not been finalized.

The wet process residue site would have potential capacity for approximately 3.7 million cy of material under the current Feasibility Determination. Under the ROD Remedy, it is conceivable that the area proposed for the MSW site and wet process residue site could be used to site a temporary NR 213 dewatering facility for the sediment, with the dewatered sediments then transferred to a monofill at the Brown County VandeHey site and/or Onyx Hickory Meadows sites. Any temporary NR 213 facility at this location would have to be abandoned prior to 2021, when the MSW site is slated to take waste as part of the Tri-County solid waste agreement. As discussed previously, future design work could more closely evaluate the NR 213 basin size requirement.

Another alternative would be to pursue siting the temporary NR 213 dewatering facility on the adjacent Brown County property located south of the Brown County South landfill location and then transferring the dewatered sediment into the wet process residue site at Brown County South. Figure 4-9 shows the location of Brown County South relative to additional Brown County property holdings. In either case, the disposal capacity of the wet process residue site at the Brown County South site, on its own, would not be enough to handle all of the ROD Remedy volume.

Given the age of the original Feasibility Determination, it is possible that the State would require the Feasibility Determination to be updated before the Plan of Operation is completed for the wet process residue site. Future stakeholder interactions would be necessary to determine the course forward.

Brown County VandeHey Site

The Brown County VandeHey site has some similar physical characteristics to the Brown County South site, such as location (11 miles from RM 3.5), MSW capacity and a separate proposed 3.7 million cy capacity wet process residue area. Significant differences include where the facility is

within the permitting and siting process. For example, the VandeHey sites do not have a completed Feasibility Study. (The Feasibility Study was submitted to WDNR in 1994, but was subsequently withdrawn by the County.) In addition, since the siting process was put on hold by Brown County in 1994, residential development has continued to expand in the area surrounding the VandeHey site. These issues would have to be addressed in order for the VandeHey site to be a viable alternative. The total area of the VandeHey site is 154 acres. Therefore it would not be feasible to construct both the NR 213 dewatering basin(s) and the NR 500 disposal cells on the same site. However the VandeHey site could be suitable for disposal of dewatered sediment from another NR 213 basin location, following completion of the permitting and siting process as described above. Between the Brown County South wet process residue site and the Brown County VandeHey sites, sufficient capacity would exist for disposal of all the dewatered ROD Remedy sediment.

Onyx Hickory Meadows Landfill Site

The Hickory Meadows Landfill site is located approximately 30 miles from OU 4 (RM 3.5), and is projected to have approximately 3.7 million cy of airspace remaining in 2008. The local agreement allows for the disposal of PCB contaminated sediment at the site.

Onyx is contemplating pursuing a 7 million cubic yard expansion of this facility, anticipated to be ready to accept waste in 2010. The facility would have to go through the Feasibility and Plan of Operation approval process for the expansion. If the Hickory Meadows site is utilized for sediment disposal for the ROD Remedy, siting of the temporary NR 213 dewatering facility would need to be accomplished on suitable property within the 20 mile radius of the cleanup project. Once dewatering is complete, then the sediment would need to be transported to the Onyx landfill, or to one of the Brown County sites listed above, as well as the Onyx site.

Table 4-9 lists the five facilities (three non-TSCA and two TSCA) that emerged from the implementability evaluation. These facilities and associated handling and transport processes, are summarized graphically on Figures 4-2 and 4-8.

4.2.4 Modifying Criteria – Step 4

Application of Modifying Criteria is the fourth and last step for screening the disposal alternatives. Modifying Criteria include items such as social and political acceptance, and are often more difficult to quantify. The modifying criteria applied to this evaluation focus on the siting/permitting steps that would need to be completed to bring the facility on-line. As part of the siting/permitting process, additional stakeholder discussions will need to occur, as discussed in Section 9.

Of the three potential alternatives for disposal of the ROD Remedy sediment volume, two are associated with Brown County's proposed solid waste facilities. Figure 4-8 summarizes the potential dewatering and disposal alternatives following the screening process described in this section.

4.3 Initial Screening of Beneficial Use Opportunities for Suitable Material

Beneficial use of dredge material is an alternative being evaluated under both the ROD and Optimized Remedies. The concept is to segregate sand from other fractions of the dredge material from OUs 2 to 5. For the ROD Remedy, approximately 530,000 cy of sand could be separated for potential beneficial use. Desanding and beneficial use volumes will be refined during later stages of RD.

Beneficial use is defined as the use of dredge material (or some portion of it) as a resource instead of disposing it as a solid waste. This involves using the dredge material for some productive use, such as habitat creation or restoration, landscaping, soil/material enhancement, construction fill or land reclamation. The benefits can be derived from the dredge material itself or from the placement of it on a site. By definition, beneficial use does not include disposal into a landfill or other permitted facility such that disposal capacity will be used by the material. In order to meet the definition of beneficial use, the material has to have some benefit for construction or operation, or allowing for facility expansion.

Dredge material can have significant value if applied for beneficial use. These benefits can be realized through planning and coordination between the regulatory agencies, potential users of dredged material and other interested stakeholders. Selecting the most appropriate beneficial use alternative of dredge material for a given situation requires an evaluation of the physical and chemical characteristics of the material, defining how the material can be safely used, and understanding how various stakeholders interests can be integrated into the project.

4.3.1 Desanding Technologies

The Treatability Testing Report for the separation of sand fractions from PCB-containing sediments collected from OUs 2 to 5 is presented in Appendix C to this BODR. These tests reveal that physical separation technologies, specifically desanding with organic flotation and attrition scrubbing could be employed to separate relatively uncontaminated (less than 1 ppm) sand fractions (+200 mesh or 0.0029 inches) from sediment fractions containing higher PCB concentrations. Using this technology, roughly 30 percent (by weight) of the total sediment solids in the dredge slurry could be separated as sand containing less than 1 ppm PCBs. This sand fraction would be available for beneficial use.

As determined from the RD bench-scale tests (Appendix C), the most effective means to accomplish separation of sands containing less than 1 ppm PCBs from the other OU 2 to 5 sediments is to first separate greater than 200 mesh material from the rest of the dredged slurry. The incoming slurry will initially enter double-deck grizzly screens to remove coarse material and debris. The dredge slurry will then go through a vibratory wash screen (greater than the No. 200 sieve or 0.0029 inches) and spiral washer, followed by attrition scrubbers. This will liberate sand fractions from PCB-contaminated fractions. The attrition-scrubbed sand fraction will then go through traditional floatation technology (e.g. DAF) for removal of any remaining humic matter, then through a hydrocyclone and dewatering screen to separate out the sand. This resultant sand fraction is the material slated for beneficial use. A front-end loader or other traditional earth moving equipment will then be used to move the sand to the designated on-site storage area.

The remaining slurry consisting of PCB-contaminated fractions (finer than No. 200 sieve) and humic material will be pumped to the passive dewatering facility. A process flow schematic of the desanding technology is provided in Figure 4-10.

4.3.2 Materials Potentially Suitable for Beneficial Use

As discussed in Appendix C, sediment PCBs in OUs 2 to 5 are largely adsorbed onto the fine-grained soil fractions of the sediment. The fine grained fraction is defined as the percent passing the No. 200 sieve (P200), or commonly referred to as the silt- and clay-sized particles. The coarse-grained fraction of sediment is under consideration for beneficial use. Approximately 530,000 cy of sand containing less than 1 ppm PCBs are anticipated to be available under the ROD Remedy if desanding technologies are applied to the entire 7.3 million cy non-TSCA dredge volume in OUs 2 to 5 (see Table 4-1).

The chemical criterion established for most beneficial uses of dredge material is less than 1 ppm total PCBs, as discussed in Section 4.3.3, below. Desanding, with organic flotation and attrition scrubbing, has shown that total PCB levels of less than 1 ppm can be achieved.

4.3.3 Description of Potential Beneficial Use Alternatives

A primary reference source for information regarding beneficial use is "*Testing and Evaluating Dredged Material for Upland Beneficial Uses: A Regional Framework for the Great Lakes*" (Great Lakes Commission, September 2004). Appendix A of this reference summarizes case studies regarding beneficial use. The document also includes contaminant criteria for various beneficial use applications for many of the Great Lakes States. Specific contaminant levels are not presented for Wisconsin. Most of the regulatory PCB concentrations that would typically apply for a given beneficial use application are less than or equal to 1 ppm. Many of the beneficial use applications

allow higher concentrations. Determination of specific criteria for a given application would involve details that are unique to each situation.

Beneficial uses of dredged material commonly include shoreline stabilization, habitat development, beach nourishment, parks and recreation, agriculture uses, construction/industrial uses and road sanding in the winter. These general alternatives are then tailored to accommodate the particular project needs and logistics taking into account the following factors:

- Physical characteristics of the material
- Chemical characteristics of the material
- Local project/needs
- Regulatory issues
- Environmental issues, and
- Stakeholder issues

For the OU 2 to 5 RD, the following list of potential alternatives was selected for further evaluation:

ID	Beneficial Use Alternative	Description of Alternative
A	Bayport diposal facility	Beneficial use for contruction materials as part of disposal facility operations and/or construction
B	Beach nourishment	Construction materials for beach restoration. No specific sites identified. Could be in Great Lakes states.
C	Landfill construction	Contruction materials as part local operating landfill(s). Multiple opportunities, including GP landfill
D	Manufactured soil	Mix separated sand with other yard waste, agricultural waste and/or animal waste
E	Renard Island closure	Construction materials for closure of Renard Island dispsal facility, consistent with draft closure plan.
F	Sediment base cap	Construction material for sand layer in OU 3 & 4 caps as part of the Optimized Remedy
G	Roadway construction	Contruction materials for local road construction projects. No specific projects currently identified.
H	Upland development	Contruction materials for local development or park enhancement. No specific projects currently identified.
I	Wetland construction	Construction of wetlands. No specific projects currently identified

The following sections provide a description of each alternative potentially available for beneficial use opportunities.

4.3.4 Bayport Material Disposal Facility

Bayport Material Disposal Facility (Bayport) is designed as an upland confined disposal facility owned and operated by Brown County. The facility was built to manage non-hazardous (e.g., low leachability) dredge material from the Lower Fox River and shipping channel of Green Bay. The

facility is located approximately 1 mile west of the mouth of the Fox River. Construction of the facility was completed in 1999.

The facility is operated as a dredge material re-handling and storage facility. Historically, sediment has been mechanically dredged as part of various maintenance projects on the Lower Fox River and Green Bay, and barged to an off-loading facility at the Fox River Dock slip. From there, dredge material with typical solids content in the range of 30 percent (by weight) is trucked to a dewatering cell at the Bayport facility. After the material is allowed to dewater for 2 to 3 years in a dewatering cell, it is excavated and stockpiled in a stockpile cell. When materials are excavated from the dewatering cell, the drainage system and base of the cell are reconstructed for future placement of new dredge material.

Depending on the schedule for navigational channel dredge projects, the Bayport facility operates in cycles, with dredge material initially deposited in a dewatering cell. The dewatered sediments are then excavated with conventional earth moving equipment and transported to one of two storage/disposal cells where it is stockpiled and graded. The site has a remaining capacity of approximately 1,750,000 cy as of January 1, 2006. As of January 1, 2008 the remaining capacity is expected to be 1,300,000 cy.

Brown County has an ongoing demonstration project, initiated in 2001, to construct a test fill area to generate data to justify a future request for steeper side slopes and greater depth of fill that could increase the facility design capacity from 2.5 to 7.4 million cy.

The beneficial use concept for Bayport could be to use segregated sand (less than 1 ppm) removed from OU 2 to 5 to complement current operations such that the capacity of the facility can be increased beyond the proposed 7.4 million cy. This could include placement of internal dewatering layers constructed with the segregated sand to improve sediment dewatering, increase the strength, and allow for steeper/higher final grades. Other changes may be possible to lower operating costs and increase the capacity of the facility. Additional evaluation will be necessary to assess this alternative for beneficial use.

4.3.5 Regional Beach Nourishment

Beach nourishment is currently the most common beneficial use of dredge material in the Great Lakes. Beach nourishment is a low cost, beneficial option for operation and maintenance of dredging projects in the USACE Detroit District. Many of the District's harbors provide clean, sandy material from the navigation channels that is then transferred to nearby beaches in order to mitigate normal erosion effects of wind, waves and weather. Beach nourishment also returns sediments trapped between breakwaters into the littoral drift process and aids in the stabilization of beaches.

When developing dredging plans for a particular project, areas of erosion are considered for beach nourishment opportunities. The distance from the dredging areas is also considered, since this directly affects the cost of the operations. Other important factors include the locations of parks and public facilities, such as water intakes, and the condition of the shoreline near them.

Material not suitable for placement on a beach could be evaluated for other uses such as construction and industrial fill and habitat development. Because of the likelihood of human and wildlife contact with beaches, as well as the potential for leaching into near shore waters, contamination limits are often strict for this application and will need to be evaluated on a case by case basis. In some cases, the background levels measured at the site are applied as a benchmark.

Beach nourishment operations must comply with state water quality regulations according to Section 401 of the CWA. Section 404 of the CWA and the Coastal Zone Management Act also apply. In Wisconsin, beach nourishment is allowed only for Great Lakes locations, not inland waters, per NR 347.07(4). Under the general permit, the acceptable PCB concentration for beach nourishment is less than 0.05 ppm total PCBs. NR 347 lists two additional criteria, grain size and color. Risk to beach users is addressed qualitatively by limits placed on the source material. Grain size is limited by requiring the P200 fraction to be no more than 15 percent (by weight) of the average fines content of the native beach material. Color is qualitatively required to be a close match to existing beach color.

Use of segregated sand from OUs 2 to 5 for beach nourishment is under consideration, but no specific projects are identified at this time. Therefore, specific evaluation criteria such as physical or chemical suitability, volume required, distance to from the site to the beach location, etc. are not known at this time.

4.3.6 Landfill Construction

This alternative involves beneficial use of dredge material in the construction or operation of an upland solid waste landfill. Examples of construction use include external berms either inside or outside the containment liner system, use in the leachate collection system or use in the final cover system. A potential operational beneficial use is for daily cover.

At some landfill sites, on-site or import soil is used for construction of external berms to achieve additional capacity or due to other site constraints. The segregated sand from OUs 2 to 5 could be suitable for external berm construction at landfill sites. Granular material is used as part of the leachate collection system at landfills. Final cover is used during closure of municipal solid waste (MSW) landfills to provide a barrier between the landfill wastes and the surface. Physical and contaminant criteria will be dependant on the type of waste and other design considerations such as slope stability and erosion. Most final cover systems include a clay barrier layer, root zone and topsoil layers. Some landfills also have a gas venting layer placed below the final cover system. The

segregated sand from OUs 2 to 5 may be suitable for the root zone layer, or possibly the topsoil layer if mixed with other organic materials (see manufactured topsoil alternative). Segregated sand suitable for use in a leachate collection system or for final cover would have to meet permeability and gradation requirements to be used as drainage media.

Landfills use daily cover to prevent odor and litter from escaping the landfill. Daily cover is a thin layer of material, typically 6 inches thick, laid over the waste each day. Materials suitable for daily cover include most grades of soil and sand. Because of the limited direct routes of exposure from a landfill it is likely that daily cover will allow a higher level of contamination than other uses. This option may be dependent upon the final PCB concentration of segregated sand materials.

As with the other alternatives, the distance between OUs 2 to 5 and the landfill site is a significant factor in the economic viability of this alternative. Specific MSW landfills have not been contacted to evaluate their need or interest in beneficial use of segregated sand from OUs 2 to 5. A next step in the evaluation will be to contact local landfill owners identified in Section 4.2.1.

Beneficial use as a daily cover is defined in NR 538.10(4). According to NR 538.10(1), use for daily cover, if it can be shown to substantially eliminate leaching or emission of contaminants, the material will likely require a Category 5 or better industrial by-product as defined in NR 538.08. Additional regulations that could influence the use of dredge material for daily over include NR 506.05, which requires MSW landfills to use a daily cover of 6 inches, NR 506.055, which allows approved alternative materials to be used for this purpose, NR 500.08(5), which allows exemptions from solid waste regulations to allow for beneficial use of materials, and the low hazard exemption defined under s. 289.43(8) Stats.

4.3.7 Manufactured Soil

This alternative involves mixing segregated sand from OUs 2 to 5 with composted organic matter such as yard waste, wastewater treatment plant (WWTP) biosolids, manure or other organic wastes to create a saleable topsoil material. The specific application for the material will need to be developed taking into account economics, locally available organic materials and the chemistry of the resulting by-product. Potential organic materials could include yard waste, sewage sludge, manure from large-scale farms or animal organic waste from local meat packers. There is also an accumulating body of scientific evidence that shows composting dredge material with organic carbon sources is an effective way to remove or immobilize organic contaminants such as PCBs.

Several examples of this approach have been successfully carried out within Wisconsin and the Great Lakes, as follows:

- Dredge material high in nutrients, removed from Frankfort Harbor, Michigan, has been utilized to reclaim land for farming purposes. The land owner planned to develop an orchard over the reclaimed 20 acres.
- At the Milwaukee CDF, the USACE has been involved in a demonstration project to treat dredge material through composting with other organic materials so produce a safe topsoil product that can be sold commercially. (The results of this pilot project are available at: http://el.erdc.usace.army.mil/dots/doer/pdf/doerc33.pdf.) For this project, dredge material was placed in rows of mounds over wood chips and sewage sludge. The biomound rows are periodically turned to provide increased oxygen to facilitate biodegradation. It was shown that total PCB concentrations were reduced to levels not considered a risk by USEPA standards, although a standard was not provided in the report. Preliminary market studies indicate that the product could sell for about $10/cy, which will offset the cost of treating the dredge material. A similar project has been evaluated by Brown County.
- The Toledo-Lucas County Port Authority has a demonstration project that involves a partnership between the Port Authority, the City of Toledo and a private topsoil manufacturing company. Under contract to the City, the company recycles the City's sewage sludge for a fee and provides the City with 4 cy of topsoil for every 1 cy of sewage sludge. The company creates the topsoil by mixing the sewage sludge with dredge material and lime sludge, a by-product of the drinking water treatment process. The resulting topsoil has been used extensively as the final vegetative cover for the city of Toledo's landfill. The material also has been used for landscaping at a State Park, at the Toledo shipyard, at a local park and along roadways. The Port is expanding the acreage available for dredge material composting to create a program for permanent commercial-scale dredge material recycling.

The Fox River Valley is home to food processors, municipal wastewater treatment and solid waste facilities, paper mills, wood manufacturers and livestock producers. This region also represents one of the fastest growing urbanizing populations in Wisconsin. Increasing competition and restrictions on land spreading, rising landfill costs and loss of agricultural land to urban development have led farmers and industries to seek alternatives to direct land spreading and/or landfilling of their organic wastes.

A study to evaluate organic waste in the Fox River Valley has been completed by the Fox River Valley Organic Recycling (FRVOR) project (Preferred Consulting Group 2003). The FRVOR project was initiated to evaluate the economic, technical, organizational and regulatory feasibility of centrally processing organic wastes to produce soil amendments. FRVOR has had involvement from local wastewater utilities, industry members, large scale farms, WDNR and other interested stakeholders. Additional evaluation of this alternative is required to better understand the economic and environmental viability of this alternative in the local market in the Fox River Valley.

Wisconsin regulations that address composting of organic wastes are covered in NR 502.12. Composting of other wastes is addressed under NR 502.08. If the dredge material has residual contamination, it might be allowed to be beneficially used under the low hazard waste exemption, but it will still be considered a regulated solid waste. NR 538 addresses beneficial use of high volume

industrial waste, and contains tables of values for leach test and bulk solids concentrations for several parameters.

4.3.8 Renard Island Closure

The Renard Island CDF was constructed in 1978 by the USACE for storage of dredge material from maintenance dredging of the Green Bay navigational channel. Renard Island is approximately 54 acres in size. Approximately 2,700,000 cy of dredge material was deposited in the Renard Island CDF from 1978 through the early 1990's. Sediment was mechanically dredged and transported to Renard Island by barge. Since the early 1990s, the USACE has suspended use of Renard Island and has used the Bayport facility as its primary storage facility for navigational channel dredge materials.

WDNR has requested that Renard Island be closed in accordance with rules regulating the closure of a solid waste disposal facility subject to Wisconsin regulation under ch. 289, Wis. Stats. The draft closure plan includes a grading plan, final cover system, and surface water and erosion control plans (Foth & Van Dyke, July 2005).

The proposed final grades will be placed at a slope of between 3 and 10 percent. These slopes were designed to accommodate settlement of the placed dredge material (grading layer) as the material dewaters while maintaining positive drainage post-settlement. Based on the current site topography the proposed grading plan could provide Renard Island with an additional 640,000 cy of capacity for general dredge materials, excluding the final cover. All or part of this airspace could potentially be used for beneficial use of the segregated sand removed from OUs 2 to 5; however, given ongoing local issues regarding Renard Island closure, this option at Renard Island may be less likely than other beneficial use options.

4.3.9 Roadway Construction

Several projects in the Detroit District of the USACE have utilized dredge material in construction such as general fill for roadway embankments or bridge crossing, dike construction, urban and industrial use parking lots and road sanding. For example, at the Erie Pier CDF in Duluth, Minnesota dredge material is washed with on-site water to wash away the fine material leaving clean sand. The clean sand is then used for various construction and industrial applications, including roadway construction.

This is a general category that shows significant promise for beneficial use of desanded materials from OUs 2 to 5. Specific project location(s) have not been identified at this time and need to be pursued in order to make this alternative viable. It is possible that State, County or Town roads could be used for this application. For example, significant road construction is planned in Northeastern Wisconsin over the next decade. Some portions of this work will likely occur in low lying areas

where sand fill will be required to bring the roadway embankment to grade. In addition overpasses will require embankments to be constructed out of suitable material such as clean sand.

Important issues that will affect the feasibility of this alternative include distance to the road construction site from OUs 2 to 5, construction schedule for both projects, and the possibility for containment of the imported backfill material. Discussions with WiDOT and local units of government need to occur to complete a more detailed economic and technical feasibility of this alternative.

Wisconsin regulations that address restricted fill are defined in NR 538.10(5-8). These include confined geotechnical fill and encapsulated transportation facility embankments, which require at least a category 4 material. Unconfined geotechnical fill and capped transportation facility embankments will have the more stringent requirements of a category 3 material. The requirements for these material categories are defined in NR 538.08(3-4) and in NR 538 Appendix E, tables 2-3.

4.3.10 Upland Development

This is a general category that was identified during preliminary discussions on beneficial use. In general, this application includes placement of clean fill or a soil cover over Brownfield sites that are being redeveloped, or a green field site that requires imported fill as part of site construction.

For the Fox River, this concept involves numerous opportunities for developing properties along the navigation channel in the Port of Green Bay. In order to make these properties suitable for commercial use, various site improvement activities will need to occur, such as the following items:

- Dredging to allow for large boat access;
- Installation of a dock wall;
- Backfilling behind the dock wall to the bulkhead lines; and
- Site preparation costs such as rail access and specific infrastructure needs.

The segregated sand from OUs 2 to 5 will be suitable for backfilling behind the dock wall from a geotechnical standpoint. Contaminant limitations will likely vary depending on the intended use of the property and existing or background contaminant levels present at the site. Industrial or commercial use will be the preferred end use of the site as residential use will likely have more restrictive requirements. Design of the site could include appropriate engineering controls to minimize environmental concerns associated with this application.

One identified application of the upland development option is to integrate beneficial use with construction of the staging area, as discussed in Section 3.7. In addition, discussions with the City of Green Bay, Brown County (Port Authority), regulators, potential commercial interests and other

stakeholders will need to occur to perform a more detailed evaluation of this alternative. It is conceivable that some or all of the segregated sand could be used for one or more of these development projects that will have a significant positive impact on the local economy and revitalization of the area along the Fox River.

Surface cover or general backfill are not specifically addressed in NR 538. Therefore, classification as a Category 1 material according to NR 538.12(3) and an exposure assessment according to NR 720.19(5), will likely need to be conducted prior to this application. The specific requirements for category 1 materials are defined in NR 538.08(1) and in NR 538 Appendix E, tables 1A and 1B.

4.3.11 Wetland Construction

This is a general category that was identified during preliminary discussions on beneficial use. Specific project location(s) have not been identified at this time and will need to be pursued in order to make this alternative viable. Wetlands typically occur in fine-grained soils that have a high organic content. Given the material under consideration for beneficial use is sand with low organic content, it is not likely a suitable material for wetland construction.

4.3.12 Sediment Cap Base Material

Sand materials segregated from the dredged material may be suitable for beneficial use as part of the lower layer of nearshore (shoreline) caps. As described in more detail in Section 5 below, sediment caps are designed to accommodate a variety of sediment and river conditions, and range from 13- to 33-inch-thick sand caps covered with different armor material, as appropriate for the specific capping location. Depending upon location-specific isolation zone and mixing zone characteristics, segregated sand (i.e., less than 1 ppm PCBs) may be potentially suitable for use as the base layer below the cap bioturbation layer. This base layer would then be covered with the appropriate armor material (sand, gravel, cobble, or quarry spalls depending on the erosion potential at a particular location), as described in Section 5.

Prior to placement in the river, stockpiles of the material would be analyzed for PCBs to ensure that the desanding process (physical separation with organic floatation and attrition scrubbing) successfully reduced the PCB concentrations of the material to a level suitable for use in the river (e.g. less than the RAL of 1 ppm). Additional material specifications for the cap materials will be evaluated further as part of subsequent design phases. These specifications may include such items as gradation requirements, filter and permeability compatibility, shear strength, and consolidation estimates. Although beneficial use of segregated sands might provide an effective complement to capping, use of segregated sand as base materials for sediments caps is anticipated to be less likely than other beneficial use options presented in this BODR.

4.4 Screening of Beneficial Use Alternatives

The focus of the beneficial use evaluation in this BODR is to provide a description of the alternatives that have been considered, and to provide a framework or process with which to screen the alternatives going forward. The first step was to identify a range of potential alternatives that may be feasible based on previous knowledge of beneficial use and local needs/projects. The previous sections provide a description of the alternatives and will be used to provide a platform with which to discuss the alternatives in more detail with the various stakeholders. These future discussions are required to fully evaluate the economic, regulatory and technical feasibility, as well as sociopolitical acceptability, of the most likely alternative(s).

This section of the BODR identifies a proposed framework for the ongoing evaluation of the most likely alternative(s) for beneficial use. At this stage, ranking or scoring of the alternatives has not been attempted, since, in some cases a specific project has not yet been identified or discussions with the key stakeholders have not begun.

4.4.1 Initial Screening

The first step in the proposed framework is to identify initial screening criteria to provide a preliminary evaluation of the alternatives. Initial screening criteria could include the following:

- Compliance with regulatory requirements
- Need for ESD or ROD Amendment
- Technical feasibility
- Compatibility with surrounding land use
- Siting/permitability
- Capacity of alternative
- Constructability
- Compatible with dredge schedule
- Preliminary cost
- Sociopolitical acceptance

During the subsequent steps of the process, additional criteria have been identified and grouped into threshold, implementability and modifying categories.

4.4.2 Threshold Criteria

For step two, threshold criteria are identified to aid in eliminating alternatives that will not likely meet regulatory requirements or are not technically feasible, including the following:

- Impact on human health
- Impact on terrestrial species (meets soil standards)
- Impact on aquatic species (meets surface water standards)
- Impact on wetlands (NR 103)
- Impact on critical habitat
- Effect on surface water (NR 102, 105, 106, 347)
- Effect on groundwater (NR 140)
- Air emissions (NR 445.03)

4.4.3 Implementability Criteria

During the third step, implementability criteria will be used to rank the alternatives against each other, and include items that could have a significant effect on schedule or cost. Implementability criteria include the following items:

- Precedent within Great Lakes
- Precedent within Wisconsin
- Permitting schedule
- Compatibility with dredge schedule
- Distance from dredge location
- Transportation (pipeline, barge, truck)
- Preliminary cost ($/cy)

4.4.4 Modifying Criteria

In the fourth and final step, modifying criteria will be used to further screen the most promising alternatives. Modifying criteria include items such as social and political acceptance, and are often more difficult to quantify. These criteria are of significant importance in the evaluation of beneficial use alternatives. Modifying criteria include the following:

- Are key stakeholders identified?
- Discussions with land owner/jurisdiction?
- Net environmental benefit
- Aesthetics
- Public support

4.4.5 Evaluation Process

The potential beneficial use alternatives will then be assembled and ranked against the selected criteria in the categories described above and shown in Table 4-10. A short list of the most promising

option(s) will be identified along with supporting rationale and documentation and forwarded to the 30 Percent Design Phase of the project. The scoring process is designed as a semi-qualitative method.

The Table 4-10 matrix will be used score beneficial use alternatives on a scale from 1 to 3, with 1 being the lowest and 3 being the highest score. These numbers will correspond to colors to facilitate visual comparison, as follows:

- Red = 1
- Yellow = 2
- Green = 3

The alternatives will be evaluated sequentially within the various categories (initial screening, threshold criteria, implementability criteria, modifying criteria) as defined above. The top few alternatives following each screening step will be retained for further evaluation in subsequent steps. It is envisioned that several alternatives may survive the screening process for detailed evaluation and design. This is due to the possibility that more than one alternative may be required to achieve the desired capacity (530,000 cy under the ROD Remedy) or that more than one alternative has a high probability of success.

Data gaps will be identified as part of this scoring process. These data gaps will be filled as part of the subsequent design phases of the project. Further evaluation, selection and the design of the selected alternative(s) will also occur in later phases of the RD.

5. OPTIMIZED REMEDY

The ROD contains specific goals for the remedial action, and sets forth a remedial strategy to achieve those goals. It also contains the flexibility to allow the RD to address specific areas of the OUs in a manner consistent with the more detailed RD data. The Optimized Remedy addresses much of OU 3 and OU 4 in a manner consistent with the original strategy outlined in the ROD, but also utilizes the available flexibility, including the contingent remedy provisions of the ROD, to deal with the new information identified during RD.

As discussed in Section 1.6.2, using the considerable new information collected during RD, the Optimized Remedy uses dredging to remove most of the PCB mass in the river that would be removed under the ROD Remedy, but without the need to remove large volumes of sediment that are near or below the 1 ppm RAL. The Optimized Remedy also recognizes that because of dredge residuals or location-specific engineering, implementability, or practicability considerations, supplemental technologies must be applied to achieve the RAL and SWAC in some locations. In addition to dredging the bulk of the PCB mass that would be removed under the ROD Remedy, the Optimized Remedy includes capping in selected areas, consistent with the contingent remedy provisions of the RODs. Like the ROD Remedy, the Optimized Remedy also uses sand covers for certain areas that either have been dredged and exhibit post-dredge residual concentrations over 1 ppm, or that contain thin deposits of low concentration sediments that satisfy particular criteria to ensure protectiveness. The Optimized Remedy applies each of these remedial technologies to specific areas of the Site based on the sediment conditions of those specific areas, as shown by the new information collected during RD. Also like the ROD Remedy, the Optimized Remedy is designed to meet the SWAC goals set out in the RODs, meet the remedial timeframe set out in the RODs, and address all sediment that exceeds the RAL. This section provides technical details of the Optimized Remedy, supported by additional detail provided in appendices, and compares and contrasts the ROD and Optimized Remedy approaches.

Section 5.1 presents the overall design goals of the Optimized Remedy, and briefly summarizes the new information collected during RD, along with relevant excerpts from the ROD, USEPA guidance, and prior analyses of sediment stability. Section 5.2 discusses the development of the dredge plan for the Optimized Remedy, which was the first step in the overall design of this option. Sections 5.3 and 5.4 summarize engineered cap and sand cover design elements integrated into the Optimized Remedy, which was the second step in the evaluation. Cap design is more specifically described in Appendix D. The net effect of the blended dredging and capping elements of the Optimized Remedy on bathymetric and hydrodynamic conditions of the river is discussed in Section 5.5, building on the results of detailed hydrodynamic evaluations recently completed by USGS and others (see Appendix D). Long-term monitoring, maintenance, and institutional controls needed to ensure the permanent integrity and protectiveness of caps are discussed in Section 5.7. Sediment transport and disposal

elements of the Optimized Remedy, which incorporates additional options not applicable to the ROD Remedy, are discussed in Section 5.8. Finally, a comparative evaluation of the ROD Remedy and Optimized Remedy is presented in Section 5.9.

5.1 Design Goals

The design goals of the Optimized Remedy were developed to achieve concurrently all of the following:

- Ensure achievement of the risk-based SWACs specified in the RODs.
- Address all sediment with PCB concentrations above the 1 ppm RAL.
- Pursue PCB mass removal by dredging higher-risk deposits identified within the Site, without removing large volumes of sediment that are near or below the 1 ppm RAL or that present other engineering feasibility or practicability issues.
- Design and apply engineered armored caps alone or in combination with dredging, in specified areas of the Site where such caps provide the same protectiveness as the ROD Remedy where permanent stability and performance can be assured, and without adversely affecting navigation (commercial or recreational), flood capacity, or habitat uses of the river. The specific areas where caps could be placed either alone or in combination with dredging, as more fully described in this section, were determined based on the results of the comprehensive RD sampling and analysis program and the outcome of engineering evaluations that considered the specific characteristics of individual site areas.
- Maximize the implementability of the overall remedy, considering the constructability of different dredge and cap plans, transportation options, the availability of upland disposal facilities, and beneficial use opportunities.
- Reduce the time frame for implementation and improve cost-effectiveness relative to the ROD Remedy.

As more specifically described in this section, the Optimized Remedy includes the following:

- **Site Mobilization and Preparation**. Staging areas similar to those described above for the ROD Remedy will be needed to support the remedial action. Staging areas will also be designed to optimize other elements of the remedy such as beneficial use. Preparation for remedial actions also includes landfill disposal agreements and/or permitting, as needed.
- **Sediment Removal**. In many areas of OUs 2 to 5, sediment removal will be performed in a manner equivalent to that described for the ROD Remedy (i.e., dredging to the 1 ppm RAL with hydraulic equipment). Sediment potentially subject to TSCA disposal requirements will also be dredged with hydraulic equipment (versus mechanical dredging of these materials under the ROD Remedy), because the Optimized Remedy uses active mechanical dewatering that can accommodate all dredged sediments [see below]. A single hydraulic dredge will be used in OUs 2 to 5. As with the ROD Remedy, removal will generally occur following a high-to-low concentration and upstream-to-downstream sequence to minimize the potential for recontamination. Sediment removal will be coordinated with USACE navigation channel maintenance and environmental dredging actions as appropriate.

- **Sediment Desanding**. Similar to the ROD Remedy, desanding of dredged sediments will occur at an upland processing facility, to the extent that beneficial uses of particular volumes of the relatively clean sand have been established. Segregated sands will be beneficially used in both on-site (e.g., partial fill of the staging area) and off-site applications, to the extent that such applications have been established at the time of construction. Approximately 225,000 cy of segregated sand material is potentially available under the Optimized Remedy, all of which is targeted for potential beneficial use.
- **Sediment Dewatering and Disposal**. The lower dredging volume (compared with the ROD Remedy) allows feasible mechanical dewatering at the staging facility of all sediments dredged under the Optimized Remedy, including sediments requiring disposal at a TSCA landfill. Non-TSCA dewatered sediments will be transported by truck to a dedicated engineered landfill or other suitable disposal facility, consistent with Wisconsin Administrative Code NR 500 and other applicable regulations. Dewatered sediments potentially subject to TSCA disposal requirements will be transported by truck to a dedicated engineered landfill facility appropriately permitted to receive this waste.
- **Water Treatment**. Treatment of water generated by the dredging, desanding, and dewatering operations, as well as storm water collected from the upland staging facility, will be performed in a manner equivalent to that of the ROD Remedy, including likely sand filtration and granular activated carbon (GAC) polishing of the discharge, similar to the system used for the SMU 56/57 demonstration project.
- **Post-Dredge Residual Management**. Similar to the ROD Remedy, management of dredge residuals will likely be required to meet the overall SWAC goals, and will include placement of approximately 6 inches of sand (referred to here as a "residuals sand cover") or placement of an engineered cap on the dredged surface, as appropriate for the individual location.
- **In situ Capping.** In certain areas, where permanent stability and performance can be assured, engineered armored caps will be constructed consistent with the contingent remedy provisions of the RODs. Similar to the ROD Remedy, in situ capping of sediments exceeding the 1 ppm RAL will also be performed along shoreline areas where RD evaluations conclude that dredging would adversely affect adversely impacting the stability of the existing slopes. The use of shoreline capping will be evaluated on a case-by-case during later phases of the design. Sand covers will be placed to address surficial post-dredge residuals (see above). Sand covers will also be placed over thin deposits of low concentration sediments that meet specified criteria (discussed in Section 5.4, below) designed to ensure protectiveness
- **Demobilization and Site Restoration**. Demobilization and site restoration will be performed in a manner similar to the ROD Remedy.
- **Natural Recovery, Monitoring, Maintenance, and Institutional Controls**. Similar to the ROD Remedy, a long-term monitoring and institutional control plan will be developed as part of RD. In addition to institutional controls, monitoring and maintenance will also occur to ensure the permanent effectiveness of caps (see Section 5.7). As with the ROD Remedy, land and water use restrictions and access restrictions may require local or state legislative action to prevent inappropriate use or development of certain areas of the Site.

5.1.1 New RD Information

The Optimized Remedy is based on new data collected during the RD investigation (Shaw/Anchor 2004, 2005), which identified a number of site characteristics that are substantively different than

those contemplated at the time of the ROD. These new data determine more specifically how the RD can optimally achieve the design goals listed above, and in a manner consistent with the NCP and the RODs. Some of the findings of the new data that are relevant to remedial design are summarized below:

- Deeply buried contaminated sediments (between approximately 6 to 13 feet below mudline) are present at depth below the bottom of the authorized federal navigation channel. Representative sediment concentration profiles in the middle reaches of OU 4A (RM 4.2) and in the Fort Howard turning basin (RM 3.4) are depicted in Figures 2-21 and 2-22, respectively. These profiles reveal that relatively cleaner sediments overlie higher concentration deposits present at greater depth below the bottom of the navigation channel. These new data show stable historical subsurface sediment deposits that have not been reworked over time. The data also indicate that removal of such deeply buried sediments (neatline volume totaling approximately 0.7 million cy) would require dredging of considerable additional volumes (greater than 1.0 million cy) of less contaminated non-neatline sediments present above and adjacent to the buried deposits, resulting in a total dredging volume for deeply buried sediment areas under the ROD Remedy of approximately 1.7 million cy.
- Several contiguous areas within the Site, particularly in shallow water "bench" zones in OU 3, OU 4A, and at the mouth of the river in OU 5, are characterized by a relatively thin layer (up to 6 inches thick) of sediments with PCB concentrations between 1 and 2 ppm , such that only a relatively small amount of PCB mass is present in these areas. While such low-risk areas collectively represent only about 0.5 percent of the total PCB mass in OUs 2 to 5, such areas represent nearly 18 percent of the remedial action area and about 5 percent (roughly 400,000 cy) of the volume of sediments that would be dredged under the ROD Remedy (see Figures 2-14 through 2-19). Because of the limitations and tolerances of dredging, removal of such thin, relatively low-risk sediment deposits would result in removal and disposal of a substantial volume of sediments in OUs 2 to 5 containing PCB concentrations less than the 1 ppm RAL. Within many of these areas, the information developed since the ROD indicates that placement of either an engineered cap or 6-inch sand cover, depending on site conditions, can reliably achieve the risk-based performance objectives of the RODs.
- As discussed in Section 3, because of the undulating "neatline" surface and the necessary overdredge allowance, along with the presence of deeply buried sediments as outlined above, achieving the 1 ppm RAL with appropriate statistical confidence under the ROD Remedy would require dredging 2.0 to 2.6 million cy of sediments with PCB concentrations at or below the RAL, for a total ROD Remedy dredge volume of about 7.6 million cy (see Table 2-12). As discussed in Section 2.3, such an approach may result in unnecessary remediation of uncontaminated sediment, straining the available disposal site capacity, prolonging the cleanup process, and potentially resulting in relatively ineffective use of cleanup resources with little or no risk reduction.
- A small deposit of relatively highly contaminated near-surface PCBs has been identified in upper OU 4A (RM 6.6). Along with the rest of the post-ROD data, these data indicate that PCB mass is not uniformly spread throughout OU 4, but tends to be concentrated in smaller definable areas. (Note that because of relatively high PCB concentrations near the sediment surface [to 3,000 ppm; see Figure 2-20], the RM 6.6 area is being considered by USEPA and WDNR for early remedial action in 2007, ahead of the implementation schedule for the rest

of OUs 2 to 5. Remedial action agreements for this area are currently being developed, and are not addressed in this BODR.)

- In recognition of the current "caretaker" status and the lack of maintenance of the OU 4A navigation channel, and following local agency approval, Congress is expected to complete the formal reauthorization of the OU 4A channel from its prior depth of 18 feet to a depth of 6 feet (see Section 2.2.2.3). This change will further ensure that deeply buried, stable deposits present below the OU 4A channel will not be disturbed, as such sediments are up to 15 feet below the bottom of the reauthorized channel.
- Substantial thicknesses (more than 13 feet in some locations) of contaminated sediments were detected in several developed shoreline areas of OU 4, such as immediately adjacent to the SMU 56/57 demonstration project. In these areas, it may not be practicable to dredge all buried contaminants (including localized subsurface sediments potentially subject to TSCA disposal requirements), as such an action could adversely impact shoreline infrastructure. Even under the ROD Remedy, these nearshore areas could require engineered capping or other remedial approaches to achieve an implementable remedy that is protective of human health and the environment (see Figures 3-1 and 3-2). Detailed evaluations of each of these shoreline locations will be performed as part of the 30 and 60 Percent Designs following a detailed shoreline survey and review of as-built records of existing structures.
- The limitations of modern dredging equipment to remove contaminated sediments have recently been documented (e.g., see Section 3.6.4). Post-dredge sediment residuals, which can make achievement of risk-based goals difficult in dredging-only remedies, are now understood as inevitable due to the inability of any existing dredging equipment to completely remove all sediment within a dredge prism. Careful planning for sediment residuals in remedial design has often resulted in integration of tailored cover and engineered cap designs to achieve optimal risk management objectives (e.g., see EPA 2005b).
- As discussed in Section 4.2, there is limited landfill disposal capacity in the region (within and outside of Wisconsin) generally, and the RD work revealed that very few regional landfills have the capacity or willingness to accept the relatively large sediment disposal volumes that would be generated under the ROD Remedy. Many of the easements needed to facilitate pipeline transport of sediments from the staging area to the few regional landfills identified as potential disposal options are currently in place, but are not presently ensured as viable for the duration of the cleanup action. Moreover, various pieces of legislation have been introduced that could make landfill disposal in Wisconsin of substantial quantities of Lower Fox River sediments even more difficult (e.g., proposed 2005 Assembly Bill No. 34). These developments highlight the need for judicious use of regional landfill capacity.

5.1.2 ROD Capping Contingency

The ROD for OUs 3 through 5 sets forth a contingent remedy that includes a combination of dredging, capping, and MNR. Under the ROD, the contingent remedy can be adopted only if certain criteria are met. Based on the substantial new information developed during the RD process, the Optimized Remedy described below was developed to include elements of both the ROD Remedy and the contingent remedy.

This section discusses the criteria set forth in the ROD for developing and evaluating the contingent remedy. Because the Optimized Remedy includes both a dredging component and a capping

component, the Optimized Remedy was evaluated under those criteria. Section 5.9 provides a comparative evaluation of the Optimized Remedy and the ROD Remedy consistent with the requirements of the ROD for selection of the contingent remedy. The ROD criteria for the contingent remedy are as follows (excerpted from Sections 13.4 and 13.5 of the OU 3 to 5 ROD, which also applies to Deposit DD of OU 2; WDNR and USEPA 2003a)

"*The pre-design (RD) sampling results, the engineering requirements outlined below, and costs will provide the basis for determining whether capping will be appropriate to implement for a particular deposit or subset of deposits. Design considerations will be the basis for determination of the exact deposits that will be capped. This contingent remedy may only be implemented if it meets the following requirements:*

1. *The contingent remedy, consisting of a combination of dredging and capping, must provide the same level of protection to human health and the environment as the (ROD) Remedy. To demonstrate that a cap will provide the same level of protectiveness as the (ROD) Remedy, the following will have to be addressed: (a) the potential for PCB releases from flooding and ice scour, as well as advective and diffusional processes; and (b) the potential for a breach of the cap and how that or other potential cap failures mechanisms will be monitored.*

2. *The contingent remedy must be less costly to implement than the (ROD) Remedy.*

3. *The contingent remedy must not take more time to implement than the (ROD) Remedy.*

4. *The contingent remedy must comply with all necessary regulatory, administrative, and technical requirements, discussed below.*

5. *The capping contemplated in the contingent remedy will not be permitted in certain areas of OUs 3 and 4:*

    - *No capping in areas of navigation channels (with an appropriate buffer zone to ensure no impacts to maintenance of the navigation channel)*
    - *No capping in areas of infrastructure such as pipelines, utility easements, bridge piers, etc. (with appropriate buffer zone)*
    - *No capping in areas with PCB concentrations exceeding TSCA levels (50 ppm)*
    - *No capping in areas that do not have sufficient load-bearing capacity*
    - *No capping in shallow-water areas (bottom elevations that will result in a cap surface at elevation greater than -3 feet chart datum without prior dredging to allow for cap placement*

In addition to other controls, institutional controls unique to capping will be required to ensure the integrity and protectiveness of capped areas, including restrictions on anchoring or dredging.

Because capping relies on long-term integrity of the cap in a dynamic river environment, long-term monitoring will need to ensure that the cap will remain physically intact and chemical contaminants were contained. For example, in addition to other monitoring requirements, if there were a large storm or other event that could impair a cap's ability to retain contaminants, additional monitoring will likely be required.

Assuming the above criteria are met, capping is considered a viable and protective alternative for OU 3 and OU 4 and may be implemented. The specific areas where caps could be placed will be determined during design. Design will be based, in part, on considerations included in White Paper No. 6B – In-Situ Capping as a Remedy Component for the Lower Fox River, attached to the ROD for OU 1 and OU 2. To ensure the permanence of an OU 3 cap, permanent maintenance of the De Pere dam will be required.

The contingent remedy may be employed in OUs 3 and 4 to supplement the selected dredging (ROD) Remedy if one or both of the following criteria are satisfied. The decision as to whether one or both of the criteria have been satisfied will be made solely by the EPA and WDNR.

1. *It can be predicted with a high degree of certainty based on sampling results (taken after a sufficient amount of contaminated sediment in OUs 3 and 4 has been dredged) that a PCB SWAC of 0.26 ppm for OU 3 and 0.25 ppm for OU 4 will not be achieved by dredging alone, or*

2. *Capping will be less costly than dredging and will provide the same level of protection to human health and the environment as the (ROD) Remedy, as evaluated in accordance with the protectiveness provisions and the nine criteria in the NCP (40 CFR 300.430)."*

Consistent with the ROD criteria, the specific areas where caps could potentially be placed either alone or in combination with dredging were determined based on the results of the comprehensive RD sampling and analysis program described in Section 2 (Shaw/Anchor 2004, 2005) and the outcome of engineering evaluations that considered the specific characteristics of individual site areas. The engineering evaluations identified where caps designed according to USEPA and USCAE guidance would be permanent and protective. The results of those initial contingent remedy evaluations are summarized in Appendix D.

The Optimized Remedy deviates from the contingent remedy criteria for capping (as defined in the ROD) in four respects, based on the detailed engineering design analysis discussed in Sections 5.2 to 5.7 below:

1. The Optimized Remedy includes combinations of dredging and engineered capping in certain areas below the authorized navigation channel, where appropriate, to address deeply buried sediments and with an appropriate vertical buffer to ensure permanent stability and avoid any impact on the navigation channel.

2. The Optimized Remedy includes a combination of dredging and capping in isolated areas with PCB concentrations exceeding 50 ppm, to address deeply buried sediments or side-slope issues. Sections 5.2 and 5.3 discuss these issues in greater detail. Capping of these nearshore sediments with PCB concentrations greater than 50 ppm has been similarly identified as a potential component of the ROD Remedy, as dredging of such areas could adversely impact shoreline structures and associated infrastructure. The remedial action in these shoreline areas will be evaluated further during later stages of remedial design, based on more detailed location-specific engineering evaluations.

3. The RD analysis similarly determined that dredging in the immediate vicinity of certain utilities and infrastructure (e.g., pipelines and bridges) is likely impracticable. Capping of these areas may be a more appropriate remedial option, which would be similarly incorporated into the ROD Remedy. These locations will be identified and engineering plans developed on a case-by-case basis during future stages of the design (e.g. 30 and 60 Percent Design Submittals).

4. The Optimized Remedy includes placement of 6-inch sand covers in low risk sediment areas to more efficiently and effectively achieve the performance objectives (i.e., SWAC targets) of the ROD. For example, based on the 2004/2005 RD data, a substantial area of the OU 2-5 contains a veneer (up to 6 inches) of sediments with PCB concentrations marginally above the 1 ppm RAL, generally described as shallow "bench" areas in Section 2.3. Because of the limitations and tolerances of typical dredging equipment, attempts to remove these thin, relatively low-risk target sediment deposits would result in removal and disposal of a much greater volume of non-target sediments containing PCB concentrations less than the 1 ppm RAL. The Optimized Remedy includes placement of 6-inch sand covers to address such low risk deposits, where protectiveness can be assured. Sand cover design issues are discussed in more detail in Section 5.4.

5.1.3 EPA Sediment Guidance

The Optimized Remedy follows USEPA's December 6, 2005 *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005b), which states in relevant part as follows (from Sections 7.3 and 7.7 of the EPA Guidance):

"At many sites, but especially at large sites, the project manager should consider a combination of sediment approaches as the most effective way to manage the risk. This is because the characteristics of the contaminated sediment and the settings in which it exists are not usually homogeneous throughout a water body (NRC 2001). … Depending on site-specific conditions, contaminant characteristics, and/or health or environmental risks at issue, certain methods or combinations of methods may prove more promising than others. Each site and the various sediment areas within it presents a unique combination of circumstances that should be considered carefully in selecting a comprehensive site-wide cleanup strategy. At large or complex sediment sites, the remedy decision frequently involves choices between areas of the site and how they are best suited to particular cleanup methods, rather than a simple one-size-fits-all choice between approaches for the entire site.

Project managers should keep in mind that deeper contaminated sediment that is not currently bioavailable or bioaccessible, and that analyses have shown to be stable to a reasonable degree, do not necessarily contribute to site risks. In evaluating whether to leave buried contaminated sediment in place, project managers should include an analysis of several factors, including the depth to which significant populations of organisms burrow, the potential for erosion due to natural or anthropogenic (man-made) forces, the potential for contaminant movement via groundwater, and the effectiveness of any institutional controls to limit disturbance. In some cases, the most appropriate approach may be long-term monitoring, with contingency actions, if necessary."

As discussed below, the Optimized Remedy was developed based on a location-by-location analysis, considering the heterogeneous environmental settings present within OUs 2 to 5, to achieve a comprehensive site-wide cleanup. Detailed hydrodynamic analyses were performed in support of the Optimized Remedy to evaluate potential erosion from a wide range of natural and anthropogenic forces. Removal of contaminated sediments through dredging was determined to be the optimal remedial action at many locations. Other locations were identified for possible capping under the Optimized Remedy, such as localized areas with deep, stable deposits of contaminated sediment that are not currently bioavailable, that do not contribute to current or future site risks, and/or that would pose considerable difficulties in a dredging-only remedy. Monitoring and institutional controls were integrated into the Optimized Remedy to ensure the long-term effectiveness of the overall remedial action.

5.1.4 Sediment Stability Assessments

As noted in USEPA's sediment guidance (USEPA 2005b), sediment stability is an important consideration when evaluating particular cleanup methods. Several analyses relevant to sediment stability have occurred.

Technical Memorandum 2g, to which the OU 3 to 5 ROD refers, compared surveyed bed elevations in successive bathymetric surveys conducted by the USACE, USEPA, and USGS. The ROD inferred from Technical Memorandum 2g that scour of the sediment bed at specific OU 4 locations over periods of several years ranged up to approximately 3 feet. These long-term estimates were based on sequential USACE surveys of the federal navigation channel. The ROD describes the Technical Memorandum 2g findings as reflecting prevailing hydrological conditions occurring since 1977.

Limno-Tech, Inc. (LTI 2002) also analyzed the same sequential USACE surveys of the federal navigation channel in OU 4A, inferring apparent deposition and scour from comparisons of successive surveys. LTI concluded, after excluding dredged areas from the analysis, that areas of apparent scour occurring between 1995 and 2000 were limited to 0.5 percent or less of the surveyed area. Areas of greatest apparent scour were generally located near the boundaries of the surveyed channel area, and LTI noted several confounding factors that may have contributed significantly to

apparent scour depth in these areas. These factors included sloughing of channel slopes, and uncertainties due to bed steepness and sparser measurements near the edge of the surveyed area.

In addition to the dynamic characteristics noted within and immediately adjacent to navigation channel dredging areas, a zone of increased and highly variable turbulence in flow was noted in the upper region of OU 4A during velocity profiling surveys of the river performed by USGS during a relatively high flow event in 2004 (SEI 2005b). Detailed hydrodynamic modeling (see Appendix D), as well as observations of relatively coarse materials present in sediments in this same area, further corroborate the periodic occurrence of elevated shear stresses in the upper reach of OU 4A, particularly within the center portion of the river approximately ½-mile immediately downstream of the De Pere Dam. As discussed in Appendix D, the center portion of the channel extending approximately 1,400 feet downstream from the De Pere Dam is also potentially subject to deposition of frazil ice, which could increase river flow velocity to a point where scouring of fine-grained bottom sediments could occur. Engineered caps are not proposed within this frazil ice deposition area to avoid potential scour issues.

The forgoing information indicates that certain discrete areas of OU 4 might experience scour of up to 3 feet under prevailing hydrodynamic conditions, and that there is a turbulent flow and potential frazil ice formation zone in the center portion of the channel extending immediately downstream of the De Pere Dam in which a greater degree of scour could occur during extreme events. Although these conclusions do not apply across all of OU 3 and OU 4, the Optimized Remedy design conservatively assumes that, because of the possibility of redistribution under reasonable worst-case flow conditions, elevated concentrations of PCBs in these near-surface (0-3 feet below the mudline) sediments in OU 4 pose a greater risk to human health and the environment than the more deeply buried, stable, and thus lower-risk PCB deposits. The Optimized Remedy design elements address these potential sediment stability concerns.

5.2 Optimized Remedy - Dredge Plan Design

As discussed above, the Optimized Remedy builds on the ROD Remedy, in that it involves dredging to remove the bulk of the PCB mass that would be removed from the river under the ROD Remedy dredge plan discussed in Section 3. As previously discussed in Section 3, the process to develop the dredge plan includes several key steps:

- Define the dredge prism. For the ROD Remedy, as discussed in Section 3, a “neatline” delineation of sediment with PCB concentrations above 1 ppm was created, then the dredge prism was expanded beyond that neatline to take into account engineering considerations. In contrast to the ROD Remedy, site conditions were assessed for the Optimized Remedy on a core-by-core basis and preliminary remedial actions were assigned for each core area, pursuant to multiple criteria. Examples of this are provided below. These preliminary remedial actions were refined through an iterative optimization process to take into account

constructability and other engineering considerations and uniformity of remedial actions in adjacent areas.

- Select appropriate dredging equipment and staging areas for site conditions and the target dredge prism.
- Calculate dredge volumes.
- Identify and evaluate potential environmental and operational impacts caused by dredging and identify appropriate BMPs to minimize those potential impacts.

The key steps of defining a dredge prism were discussed in detail in Section 3 and are briefly summarized below to highlight similarities and differences between the two remedies.

5.2.1 Define the Neatline and Dredge Prism

The Optimized Remedy takes into consideration many criteria beyond the 1 ppm RAL, which is the predominant focus of the ROD Remedy design. Therefore, the "neatline" area, depth, and associated sediment volume were defined in a different manner for the Optimized Remedy than for the ROD Remedy. For the ROD Remedy, the neatline throughout OUs 2 to 5 was defined horizontally and vertically by geostatistical interpretation (Full Indicator Kriging [FIK] at a 0.5 level of significance) using the RD sampling data. As discussed in Sections 2 and 3, the neatline area is an idealized representation of the extent of sediments exceeding the 1 ppm RAL, and is always less than the actual area and volume of sediment that will be removed as part of construction operations (see Figure 2-23). Delineation of the horizontal and vertical distribution of PCB concentrations exceeding the 1 ppm RAL is discussed in Section 2.3.

For the Optimized Remedy, the neatline area was defined through a multi-step, iterative process. First, each of the approximately 1,400 core locations sampled during the 2004 and 2005 RD investigation was examined individually. Based on site characteristics at that location (e.g., sediment PCB concentration and mass profiles, position relative to the federal channel and low water elevations, and local hydrodynamic characteristics), the most appropriate remedial action for that core that optimizes the remedial design goals listed in Section 5.1 was preliminarily identified. These preliminary remedial actions were then refined through an iterative process to optimize the remedial actions applied to each core and across cores within a given area. Example cores are provided in Figures 5-1 to 5-4 to illustrate the initial step, as follows:

- **Core 4002-03 (Figure 5-1)**: This location is in upper OU 4A (RM 6.6). Because elevated near-surface concentrations and PCB mass are present at relatively shallow depths that hydrodynamic analyses suggest are potentially subject to erosion under worst-case design conditions (see Appendix D), dredging was identified as the most appropriate remedial technology at this location. Therefore, the Optimized Remedy element at this core location is to dredge to the 1 ppm RAL and place a 6-inch sand cover as needed for dredge residual control.

- **Core 4004-22 (Figure 5-2)**: This location is immediately downstream of the De Pere Dam (RM 6.5), in an area that (based on hydrodynamic modeling) may be subject to turbulent erosion during peak (100-year return period) flood events. Similar to core 4002-03, dredging was identified as the most appropriate remedial technology at this location, and therefore the Optimized Remedy action at this location is to dredge to the 1 ppm RAL and place a 6-inch sand cover as needed for dredge residual control.
- **Core 4032-06 (Figure 5-3)**: This location is within the reauthorized OU 4A navigation channel (RM 4.2), where deeply buried contaminated sediments are present at depths greater than 10 feet below the bottom of the federal navigation channel. Cleaner sediments are present at near-surface depths, indicative of a stable deposit. Hydrodynamic modeling of this area also confirmed the stability of this deposit under reasonable worst-case flood, seiche, and propeller wash events (see Section 5.3 below). Dredging this deeply buried deposit would result in removal of a large volume of surrounding cleaner sediment. However, in order to remove a potential encumbrance of the navigation channel and to allow normal maintenance dredging, and also to accommodate an engineered cap that will provide permanent isolation of underlying sediments, the Optimized Remedy at this location includes dredging to elevation 568.3 (excluding overdredge allowance), and placement of a 1.1-foot sand and gravel cap on the newly dredged surface. This will allow at least 2 feet of clearance between the final cap elevation and the authorized navigation depth. This dredge plan equates to cutting to 2.5 feet below the existing mudline Cap design details are described in more detail in Section 5.3.
- **Core 3011-06 (Figure 5-4)**: At this location in upper OU 3, a surficial veneer (0 to 10 cm; 0 to 0.3 feet) of sediments with a PCB concentration of 1.4 ppm overlies clean sand and silt materials with PCB concentrations well below 1 ppm. The total PCB mass per unit area at this station is approximately 0.3 gm/m2, a relatively low value for the site and also less than many areas of the Site with PCB concentrations less than 1 ppm (compare Figures 2-14 to 2-16; see Section 5.4). Dredging at this location would remove a much greater thickness of underlying clean sediment (less than 1 ppm PCBs) than the target materials (see Figure 2-23). Therefore, the Optimized Remedy element at this location is placement of a 6-inch cover layer of sand to ensure that the SWAC is attained.

The Optimized Remedy Design Memo (Shaw/Anchor 2006b) presents a detailed core-by-core summary of the Optimized Remedy, providing information on sediment PCB concentration profiles, comparisons of mudline elevations with stability benchmarks, and other relevant design information. All of these data were evaluated together to determine the preliminary remedial action at each location.

Once the core-by-core evaluation was completed as outlined above, the second step of the process was to develop a “mosaic” of remedial actions applied across OUs 2 to 5 to identify and group areas of common remedial actions (e.g., dredge to 1 ppm, dredge-and-cap, etc). In this step, remedial actions and groupings were applied to the entire Thiessen polygon areas associated with each core location. Then the mosaic was examined for apparently isolated remedial action “outliers,” and actions in some Thiessen polygons were adjusted to be more compatible with remedial actions in neighboring areas. For example, if the preliminary remedial action for a particular area was to apply a cap, but several neighboring areas were preliminarily designated for dredging such that a side slope

would extend into the subject area, the final remedial action for that area might be dredging, rather than capping, in order to achieve a more uniform and constructable dredge surface. Limited areas were identified as requiring further engineering refinement (e.g., to determine more precisely dredge cut and/or cap designs), which would be performed as part of the 30 and 60 Percent Designs. Mosaics of remedial actions developed for the Optimized Remedy, as refined through the optimization process, are presented in Figure 5-5 for OU 2/3 and in Figure 5-6 for OU 4/5. Similar to the shoreline areas discussed in Section 5.1.1, areas requiring further engineering refinements during later stages of the RD are denoted on the Optimized Remedy mosaic maps by hatching.

Application of the first two steps of the process, as outlined above, resulted in the identification of areas in OUs 2 to 5 that shared certain common circumstances. General characteristics of common dredge areas included in the Optimized Remedy are provided below.

- **Sediments Potentially Subject to TSCA Disposal Requirements** – Surficial and subsurface sediments potentially subject to TSCA disposal requirements, defined as described in Section 2.4.2, were targeted for dredging unless preliminary engineering evaluations indicated that removal was impracticable (i.e., if dredging would adversely impact shoreline stability; further evaluation to be completed during future RD phases). Approximately 200,000 cy, or 95 percent of the sediments targeted for dredging and TSCA disposal under the ROD Remedy, would be removed under the Optimized Remedy. It should be noted that, due to slope stability considerations, both the ROD and Optimized Remedies leave approximately 11,000 cy of contaminated shoreline sediment potentially subject to TSCA disposal requirements in-place adjacent to the SMU 56/57 project area as described in Section 3.3.2.2. In addition, the Optimized Remedy includes placement of a armored engineered cap in an isolated area within the OU 4A channel (represented by core location 4032-06 discussed above), where a relatively small volume (~10,000 cy) of deeply buried contaminated sediment is present at depths greater than 10 feet below the bottom of the federal navigation channel. Dredging of this deeply buried deposit would result in removal of a much larger volume of surrounding cleaner sediment. As with other deeply buried deposits in this general area of OU 4, the cost of removing these stable subsurface deposits would be substantial and disproportionate to the degree of environmental protection achieved. (The Optimized Remedy at this isolated location includes dredging to a depth of approximately 4 feet below the existing mudline, and placement of a 3-foot–thick cap including armoring with quarry spalls, on the newly dredged surface.)
- **Near-Surface PCB Deposits** – Near-surface sediments (defined as the upper 3 feet, based on stability considerations as generally discussed in Section 5.1.4) containing PCB concentrations greater than 1 ppm were similarly targeted for dredging unless preliminary engineering evaluations indicated that removal of such deposits would adversely impact shoreline stability (to be evaluated further during future RD phases). The neatline depth for near-surface PCB deposits was initially set at an elevation to ensure hydrodynamic stability and to accommodate a protective cap (see below), and was extended further to the 1 ppm interface depth if it could be performed cost-effectively (e.g., if the depth of the 1 ppm interface was within 1 to 2 feet of the depth needed to accommodate a cap). A representative core for the turbulent flow zone in the ½-mile reach immediately downstream of the De Pere Dam is presented in Figure 5-2, and resulted in dredging to a depth of approximately 7.1 feet below mudline at this location. As discussed in more detail in Section 5.9, overall dredging

actions included in the Optimized Remedy will remove a total of approximately 92 percent of the near-surface PCB mass from the OU 2 to 5 project areas, equivalent to the near-surface mass removal achieved by the ROD Remedy.

- **Subsurface Deposits** – Certain areas of OU 4 contain relatively deeply buried contaminated sediments, often at depths greater than 10 feet below the bottom of the federal navigation channel. Dredging of such deeply buried deposits would result in removal of a much larger volume of surrounding cleaner sediment, such that the cost of removing these stable subsurface deposits is substantial and disproportionate, providing little or not net environmental protection. In these areas, dredging was performed to a depth determined to be hydrodynamically stable (see Section 5.5), and to accommodate an engineered cap appropriate for that specific location that would not interfere with navigation and maintenance dredging activities (see Section 5.3). A representative core for dredge-and-cap areas is presented in Figure 5-3.

The third step in the definition of the neatline for the Optimized Remedy was to refine the boundaries of areas identified with a common remedial action to correspond with the horizontal and vertical boundaries of the controlling dredge design criterion (e.g., FIK contours of the depth to 1 ppm PCBs, depth below the bottom of the navigation channel, etc). Dredge limits were further refined to consider constructability and other limitations as described in Section 3. For the Optimized Remedy, this step frequently resulted in "smoothing" of the required dredge depth or slope across a given area, in order to achieve a more efficient and constructable design, also integrating caps in such areas as appropriate (see Section 5.3 below).

The dredging component of the Optimized Remedy was developed using the same site and project design criteria previously described for the ROD Remedy in Section 3.3.2. In summary, these criteria are:

- Maximum dredge slopes of 3H:1V for submerged areas of the site, but excluding shoreline areas. Slopes could be designed flatter, where necessary to accommodate the neat line.
- Maximum dredge slopes of 5H:1V in shoreline areas with nearby infrastructure, such as in the area of SMU 56/57, consistent with previous remedial actions at this location.
- Minimum dredge slope of 25H:1V, recognizing how a contractor will typically implement a flatter slope.
- Allowable overdepth of 0.5 feet.
- Dredging cut widths ranging from 25 to 50 feet.
- Infrastructure and structure setbacks of 10 feet or more, with more thorough examination of significant structures required as the design progresses through more detailed iterations.

Once the neatline was specified, the dredge prism was prepared. As with the ROD Remedy, the area to be dredged was simplified to establish either a constant elevation or a constant slope (over a given area). The required dredge prism was set at or below the neatline within a given area.

The preliminary Optimized Remedy dredge plans for OU 3 and OU 4 are presented in Figures 5-7(a-d) and 5-8(a-e), respectively. Example details of the preliminary dredge plan are provided in Figures 5-9 and 5-10. Representative Optimized Remedy dredge plan cross-sections are presented in Figure 5-11. While details of these preliminary dredge plans may change as RD continues, the preliminary dredge plans and cross-sections show the general mix of remediation approaches used in the Optimized Remedy. Similar to the ROD Remedy, the dredge prism for the Optimized Remedy attempts to define an optimal balance of the design goals listed in Section 5.1, balancing dredge volumes versus constructability, and ensuring that the dredge prism does not adversely affect existing structures. Section 3.3.4 describes the iterative nature of the dredge design process. By targeting more uniform dredge elevations and consistency between adjacent core locations, as discussed above, the preliminary dredge plan of the Optimized Remedy achieves a more constructable design, employing generally wider and longer dredging lanes in a less complicated network of dredge elevations and slopes (compare Figures 3-1 to 3-5 for the ROD Remedy to Figures 5-7 to 5-11 for the Optimized Remedy). (In theory, it would be possible to adjust the ROD Remedy so that it also uses wider and longer dredging lanes in a less complicated network of dredge elevations and slopes, but this would significantly increase the volume of sediment containing less than 1 ppm PCBs that would be dredged under the ROD Remedy.)

The Optimized Remedy will undergo additional iterative refinements as the design progresses to a more detailed level of completion. The discussion relating to the cost/benefit of preparing a dredge design for the ROD Remedy in Section 3.3.5 is equally applicable for the development of the Optimized Remedy. The Optimized Remedy dredge prism will be refined to achieve the best balance between dredge prism volume and constructability.

Sediments potentially subject to TSCA disposal requirements under the Optimized Remedy have been delineated in the same manner as described for the ROD Remedy (described in Section 2.4). Section 3.4 discusses in detail the methodology for developing and optimizing the dredge prism design for the ROD Remedy; this design methodology was also applied to the Optimized Remedy.

5.2.2 Sediment Characteristics

Table 5-1 presents a summary of the geotechnical properties for all samples collected during the RD investigations that were collected within the Optimized Remedy dredge prism. The sediments targeted for dredging under the Optimized Remedy are similar to those targeted for removal under the ROD Remedy (Section 3.1). The sediments can be generally characterized as soft, silty, clayey sand with an average in situ percent solids of approximately 32 percent by weight. The sediment within the target dredge prism is approximately 36 percent sand, 37 percent silt, and 26 percent clay by weight, with the remaining trace fraction being gravel-sized particles. The data presented in Table 5-1 has been corrected for coring-induced sample compaction. In addition, Table 5-1 presents a weighted average estimate of percent solids data to be used in dredge design and disposal volume

calculations, which accounts for both the vertical and spatial representatives of each sample. In some locations within the river, a layer of stiff native clay was identified beneath the soft sediment targeted for dredging.

Table 5-1. Geotechnical Properties of Sediments Targeted For Dredging Under Optimized Remedy

Parameter	OU 2/3	OU 4/5	OU 2-5
Fines Content (% Finer than No. 200 Sieve)			
Avg.[(a)]	71%	62%	63%
Std. Dev.	29%	23%	24%
Percent Solids by Wt. (%)			
Avg.[(b)]	30%	32%	32%
Std. Dev.	19%	12%	13%
Dry Density (pcf)			
Avg.[(b)]	23	25	25
Std. Dev.	25	14	15

Notes:
(a) Numerical average of measured data
(b) Weighted average of measured data (See Appendix A)

5.2.3 Equipment Selection

The Optimized Remedy generally uses the same type of dredging equipment that is described for the ROD Remedy in Section 3.2. Production rates for the Optimized Remedy are expected to be similar or greater than rates achieved under the ROD Remedy when similar pieces of equipment are applied (e.g., a single 12-inch hydraulic cutterhead dredge), owing to similar or more efficient dredge plan designs incorporated into the Optimized Remedy, as discussed above. The dredging and dewatering (discussed in Section 5.7.3) components of the Optimized Remedy have been designed to operate as independent systems with appropriate redundancies so that the productivity (or efficiency) of the dredge operation will not be affected.

Under the Optimized Remedy, hydraulic dredging instead of mechanical dredging will be used for removal of sediments potentially subject to TSCA disposal requirements. Equipment selection analyses indicated that hydraulic dredging to a nearshore staging area, with desanding, mechanical dewatering (e.g., using filter/belt presses), and truck transport to the upland landfill, is more implementable and cost effective for the lower volumes associated with the Optimized Remedy than hydraulically transporting all the sediment to the landfill using an overland pipeline. Truck transport avoids the administrative and technical uncertainties (e.g., easement uncertainties, road crossings, potential plugging, and uneven wear) that would be associated with the use of an overland pipeline to

the landfill. Such administrative and technical uncertainties could impose additional cost and time delays on the project.

Mechanical dewatering and associated equipment mobilized to the site to handle non-TSCA material will also be available for sediments potentially subject to TSCA disposal requirements. Even though all hydraulic dredging under the Optimized Remedy will be performed using the same dredge, slurry pipeline, and handling equipment (see below), these actions will be sequenced to ensure that materials requiring TSCA disposal which enter the slurry pipeline will be handled and disposed according to TSCA regulations. Such an approach, similar to the dredging design used during the 2005 Remedial Action at OU 1, will obviate the need for elaborate and expensive equipment decontamination.

Dredging of OU 4 sediments potentially subject to TSCA disposal requirements will be staggered and appropriately sequenced with the dredging of non-TSCA sediments. Initial dredging actions within OU 4 will target surficial sediments potentially subject to TSCA disposal requirements, particularly within upper OU 4A. When dredging of such sediments is completed, and an appropriate period has elapsed during which only water has passed through the pipeline, dredging and staging area operations will be converted to process non-TSCA sediments. Post-dewatering sampling of segregated TSCA and non-TSCA stockpiles will be performed (at a frequency determined during subsequent design phases) to ensure compliance with landfill disposal requirements.

Following removal of overlying non-TSCA sediments, subsequent dredging of subsurface sediments potentially subject to TSCA disposal requirements will also be sequenced in a manner equivalent to that described above. Construction sequencing is discussed in more detail in Section 6.

As with the ROD Remedy, mechanical dredging equipment and barges will be used to remove and transport debris to the upland staging area. Mechanical equipment and barges will also be used to remove isolated nearshore deposits in OU 2 and upper OU 3 and transport the material to the dewatering facility, followed by truck transport to the upland disposal site.

Dredged material transport over water will also be similar to the ROD Remedy (as described in Section 3.9), using hydraulic dredges, pipelines and floating booster stations. As discussed above, the Optimized Remedy anticipates using a hydraulic dredge to remove the sediment in areas potentially subject to TSCA disposal requirements. Some mechanical removal and barge transport is anticipated to assist in removal of debris. For the Optimized Remedy, dredged material transport over land to the appropriate disposal facilities is anticipated to be by truck rather than hydraulic pipeline. The rationale for this transport method is discussed below.

Similar staging areas are envisioned and similar weather-related impacts are expected for both remedies, with the exception of the passive dewatering operation planned for TSCA sediments under

the ROD Remedy. The duration required to achieve the required level of dewatering will be dependent on the amount of water added to the stockpile through precipitation and/or surface runoff. The shorter overall duration of the Optimized Remedy construction, resulting from a lower dredge volume, will reduce the number of seasonal shut-downs relative to the ROD Remedy.

5.2.4 Dredge Volumes

A detailed discussion of the basis for computing volumes is presented in Section 3.5.2. The methodology applied for the ROD Remedy is also applicable to computing volumes for the Optimized Remedy.

A comparison of Optimized Remedy and ROD Remedy dredge volumes is presented in Table 5-2. A total of approximately 3.7 million cy of sediments will be dredged under the Optimized Remedy, compared with roughly 7.6 million cy under the ROD Remedy (both values include the estimated volume of sediments potentially subject to TSCA disposal requirements – 210,000 cy for the ROD Remedy versus 200,000 cy for the Optimized Remedy). A detailed breakdown of sediment dredging volumes by OU are also presented in Table 5-2.

Table 5-2. Dredge and Disposal Quantities - ROD & Optimized Remedies

Remedial Action	ROD Remedy	Optimized Remedy
Dredge Volume (in situ cy)		
OU 2	81,000 [a]	24,000 [d]
OU 3	716, 000 [a]	204,000 [b,e]
OU 4 - Prospective TSCA	210,000 [c]	200,000 [b]
OU 4 - non-TSCA	6,552,000 [a]	3,258,000 [b]
Total Dredge Volume [f]	**7,560,000**	**3,686,000**
Sand Separated for Beneficial Use (cy)	530,000	225,000
Non-TSCA Disposal		
Volume After Dewatering (cy) [h]	4,721,000 [g]	1,476,000 [h]
Landfilled Total Weight After Dewatering (tons)[h]	5,604,000 [g]	1,815,000 [h]
Prospective TSCA Disposal		
Volume After Dewatering (cy) [h]	268,000 [i]	112,000 [h]
Landfilled Total Weight After Dewatering (tons) [h]	321,000 [i]	139,000 [h]

NOTES:

(a) Hydraulic dredging, desanding, and pipeline transport to dewatering basin and/or landfill
(b) Hydraulic dredging, desanding, mechanical dewatering, and truck transport to landfill
(c) Mechanical dredging, dewatering amendment, and truck transport to landfill
(d) Mechanical dredging, barge transport to staging area, mechanical dewatering, and truck transport to landfill
(e) Includes ~6,000 cy of nearshore sediment that would also be dredged mechanically as in note (d)

(f) Includes volume of sediment in shoreline areas that may not be technically feasible to dredge and may require capping or other remedial solutions (500,000 cy for the ROD Remedy and 230,000 cy for the Optimized Remedy).
(g) Includes amendment, as necessary (estimated average of 5 percent by weight) to achieve 50 percent solids by weight
(h) Includes 15 percent contingency to account for variation of in situ and dewatered percent solids.
(i) Includes 15% lime amendment to achieve 50 percent solids by weight

5.2.5 Potential Impacts from Dredging

The Optimized Remedy envisions using similar hydraulic dredging equipment as would be used for the ROD Remedy, including hydraulic dredging of materials potentially subject to TSCA disposal requirements. Thus, the potential environmental impacts from construction operations for the Optimized Remedy will be similar to those discussed in Section 3.6, although those impacts will occur over a shorter period of construction than in the ROD Remedy.

Slope and structure setbacks will likely be required in shoreline areas, although the need for setbacks will be minimized along the shoreline where capping will be performed. Details regarding the locations requiring setbacks and the design in those areas will be developed during RD pending the completion of a shoreline survey currently scheduled for the spring of 2006. Because of its lower dredge volume, the Optimized Remedy has a shorter construction duration than the ROD Remedy (see Sections 6 and 8). Thus, a commensurate reduction in impacts is anticipated, with fewer incidents of vessel interference with river traffic during the life of the project, and a reduced duration of potential air, water, and noise impacts.

5.3 Optimized Remedy – Cap Design

As discussed in Section 5.1 and 5.2, the Optimized Remedy includes dredging of contaminated sediments in many of the same areas that would be dredged under the ROD Remedy. The Optimized Remedy also includes placement of engineered caps, either in conjunction with dredging or alone, in areas where such caps would satisfy the protectiveness and cost-effectiveness criteria stated in the ROD for the contingent remedy. As part of the development of the capping component of the Optimized Remedy, a preliminary assessment of potential capping areas within the Fox River was completed using the RD investigation data. The contingent remedy cap designs and subsequent Optimized Remedy cap designs were prepared in accordance with USACE/EPA guidance (Palermo et al. 1988b) and White Paper 6B (Palermo et al. 2002). Appendix D presents these preliminary capping assessments, which were performed in accordance with the contingent remedy provisions of the ROD, but without consideration of the other Optimized Remedy concepts such as dredge-and-cap hybrid actions. These preliminary assessments explored the practical application of the ROD criteria and helped guide the development of the Optimized Remedy, as generally described in Section 5.2. Note that the Optimized Remedy includes several cap designs, each of which is tailored to meet specific conditions at various locations within OUs 2 to 5. Appendix D also presents the detailed cap designs for the location-specific caps utilized in the Optimized Remedy, which are summarized in the remainder of this section. Cap design schematics are summarized in Figures 5-12 and 5-13.

5.3.1 Cap Design Criteria

This section presents a summary of the cap design criteria that were used to develop the Optimized Remedy, based on the cap design evaluations presented in Appendix D. The thicknesses of the in situ caps for the Optimized Remedy are based on the following five components (from Palermo et al, 1998b and 2002):

- Chemical isolation of contaminants (T_i)
- Bioturbation (T_b)
- Consolidation (T_c)
- Erosion (T_e)
- Operational considerations (i.e., gas generation, placement inaccuracies, and other pertinent processes) (T_o)

An appropriate thickness of cap was determined individually for each component based on site-specific design parameters, as presented in Appendix D and summarized below. The individual component thicknesses contribute to a total cap thickness that satisfies all design components as shown in Equation 5-1 below.

$$T = T_i + T_b + T_c + T_e + T_o \qquad \text{[Equation 5-1]}$$

Consistent with White Paper 6B (Palermo et al. 2002), the erosion component and the bioturbation component may be a concurrent thickness and not independent thickness requirement. That is, a set thickness of an armor layer can serve to resist erosion as well as accommodate bioturbation. Given the variability of site conditions (PCB concentrations, erosion potential, etc.) throughout OUs 2 through 5, several cap designs were developed for the Optimized Remedy, as described in more detail in Appendix D.

Chemical Isolation of Contaminants. A series of calculations were performed using location-specific conditions (PCB concentrations, vertical groundwater velocity, sediment total organic carbon [TOC], consolidation-induced porewater flux, etc.) to evaluate the chemical isolation component of a subaqueous cap for PCB containment. Chemical isolation modeling included the use of a transient model described in Appendix B of the *ARCS Program Guidance for In Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al. 1988b) to estimate contaminant flux through the chemical isolation layer and the time to achieve steady state chemical flux conditions in the isolation layer of the cap. In addition, the steady state model of Reible et al. (2004) was used to estimate chemical concentrations in the surficial (bioturbation) sediment layers of the cap once steady state conditions are achieved.

The cap isolation thickness designs that were used to satisfy the ROD criteria incorporated the following conservative assumptions:

- For each core location evaluated for potential capping, the average sediment PCB concentration in the top 1.5 feet of sediment immediately underlying the prospective cap layer was determined, accounting for surficial sediment removal that would occur under a dredge-and-cap hybrid. For the purpose of simplifying modeling cap design, sediment deposits with PCB concentrations ranging from 1 to 9.9 ppm and 10 to 49.9 ppm were conservatively assigned values of 9.9 ppm and 49.9 ppm, respectively, for selection of the appropriate cap thickness;
- The overlying armor layer (discussed below) was conservatively assumed not to provide any chemical isolation;
- No net sedimentation was assumed on the surface of the cap, even though net sedimentation rates ranging from 1 to 2 cm/yr are typical of the prospective capping areas (given the net depositional characteristics of much of the Lower Fox River, finer-grained sediment will likely accumulate over time within the interstices of the sand/gravel armor layer);
- The bioturbation layer (and by the assumption above, the entire armoring layer) was conservatively assumed to achieve a steady state total organic carbon (TOC) concentration equivalent to existing conditions in OUs 3 and 4. The range of surface sediment TOC values was input into the steady-state model with a Monte Carlo sensitivity analysis of this model input parameter;
- The bottom 3 inches of the designed chemical isolation layer was assumed to be compromised by intermixing with underlying sediment during placement (see discussion below);
- The underlying sediment was assumed to maintain the maximum estimated porewater PCB concentration for all time without degradation or depletion due to transport into the cap;
- Conservative estimates of groundwater seepage rates into the river were used, based on regional hydrogeologic data as described in Appendix D. The range of regional groundwater flow measurements was input into the steady-state model with a Monte Carlo sensitivity analysis of this model input parameter; and
- Conservative estimates of other model parameters (e.g., PCB sorption coefficient, bioturbation, and benthic boundary layer mass transfer coefficients) were employed.

In addition to advective flow resulting from upward groundwater gradients, cap-induced consolidation of existing soft sediment may also contribute to the advective flux of porewater into the overlying cap. This cap-induced consolidation will also result in a decreased permeability and porosity of the existing contaminated sediments underlying the cap. Data from seepage-induced consolidation testing from the 2004 RD investigations were used to evaluate the effects of cap-induced consolidation on the design of the chemical isolation thickness.

Transient model results indicated that approximately 920 years would be required to achieve near steady state fluxes through a nominal 3-inch-thick chemical isolation component of the cap over existing sediments with a concentration of 49.9 ppm when the maximum regional value for hydraulic gradient was used to estimate seepage velocity. The results of the steady state model indicated that, with the cap designs incorporated into the Optimized Remedy, once steady state conditions are

achieved, there is greater than a 99 percent probability that sediment PCB concentrations in the cap bioturbation zone would be maintained (in perpetuity) below the 1 ppm RAL. This analysis considered the full range of potential bioturbation layer TOC contents from river sediment data and regional groundwater gradients. Thus, contaminant transport modeling performed for this BODR demonstrated that the Optimized Remedy cap designs will be protective of human health and the environment. The details of the isolation thickness modeling are presented in Appendix D and the results summarized in Table 5-3.

Bioturbation. Based on data collected during the RI/FS of the Lower Fox River, along with a review of bioturbation depths from other similar Great Lakes sediment systems, the potential bioturbation depth at the site is expected to be limited to the upper 5 to 10 centimeters (Palermo et al. 1998a, Clark et al. 2001). Consistent with Palermo et al (1998a), the cap design for the Lower Fox River presented herein provides an erosion protection layer component (T_e) of the cap that is sufficient for both physical isolation and bioturbation (T_b).

Consolidation. Porewater expulsion resulting from the consolidation of underlying sediments can contribute to the advective flux of contaminants into the cap. Therefore, several samples were collected for seepage induced consolidation test (SICT) evaluation as part of the 2004 and 2005 RD investigations. The relationships obtained from the SICT were then used to estimate the amount of cap-induced consolidation (and therefore volume of porewater expulsion) for a given cap thickness. However, it should be noted that the Optimized Remedy design conservatively did not consider consolidation settlement with respect to post-cap water depth within capping areas. The post-cap permeability and porosity of the sediments were also estimated from the SICT results using the relationship between void ratio and the stress level equivalent to the proposed cap thickness. Post-consolidation permeability and porosity of the existing sediments were used in the contaminant transport modeling to determine the chemical isolation thickness, as discussed below.

Table 5-3. Summary of Cap Component Thicknesses

Cap Description	Component Thickness (inches)				Total Cap Thickness (inches)	
	Chemical Isolation T_i [(a)]	Bioturbation/ Erosion T_e/T_b	Consolidation T_c	Operational T_o [(b)]	Target	Maximum
13-inch Sand/Gravel Cap	3	4	0	0 to 12 (avg. 6)	13	19
16-inch Sand/Gravel Cap	6	4	0	0 to 12 (avg. 6)	16	22
33-inch Sand/Quarry Spall Cap	12 [(c)]	12	0	0 to 18 (avg. 9)	33	42

NOTES:

(a) Includes 3 inches of potential mixing with existing underlying sediment.
(b) Includes over-placement allowance with each layer (sand and gravel or quarry spalls)
(c) The isolation thickness in this case is determined by the necessary thickness of the filter layer to support overlying quarry spall materials (see text).

Erosion-Stability of Cap Materials in Response to Potential Scour Forces. The erosion protection component of an in situ cap prevents external forces from disturbing the cap or the underlying contaminated sediments. Several potential forms of erosion discussed below were evaluated for the cap design, as detailed in Appendix D.

- Hydrodynamic flows (including seiches) – Using an extensive hydrodynamic data set collected by USGS in OUs 3 and 4, Sea Engineering Inc. (SEI) developed and calibrated a detailed 2-dimensional hydrodynamic model to predict bottom shear stresses during a design level flow event (24,200 cfs [685 m^3/s]) with a recurrence interval of 100 years (see Appendix D). The hydrodynamic model applied to OU 4 also assumed historical low water levels (576.5 feet IGLD 85; see below), concurrent with a maximum seiche amplitude of 4.3 feet (11-hour period). Initial model runs were conducted using existing bathymetry and results were used to evaluate the applicability of various cap designs under the Optimized Remedy. Following initial design of the Optimized Remedy, the detailed hydrodynamic model was run again using post-remedy bathymetry and the remedial actions refined as necessary to accommodate predicted hydrodynamic erosion forces.

  Based on the remedial action mosaics presented in Figures 5-5 and 5-6, along with cap thicknesses summarized in Table 5-3, bed elevation changes resulting from implementation of the Optimized Remedy were developed, and are presented on Figures 5-14 and 5-15 for OU 2/3 and OU 4/5, respectively. The SEI and hydrodynamic model was then applied to these post-remedy bathymetric configurations to confirm the protectiveness of the cap armor designs.

  Figures 5-16 and 5-17 show the maximum predicted shear stresses corresponding to the reasonable worst-case hydrodynamic design condition (i.e., simultaneous 100-year flows,

historical low water levels, and maximum seiche amplitude) under the Optimized Remedy bathymetric conditions in OUs 3 and 4, respectively. Relative to existing conditions, the hydrodynamic model predicted only minor changes in shear stresses throughout OUs 3 and 4 resulting from the Optimized Remedy. The maximum bottom shear stress predicted within the OU 3 capping areas is approximately 50 dynes/cm^2, and occurs in the narrow downstream portion above the De Pere Dam. The maximum predicted shear stress within OU 4 capping areas is approximately 80 to 90 dynes/cm^2, for relatively small zones within the OU 4B navigation channel. Based on these predictions, a conservative maximum bottom shear stress of 100 dynes/cm^2 was selected for design.

The design-level shear stress of 100 dynes/cm^2 was correlated to a stable median grain size (D_{50}) of 1.5-inches (i.e., gravel; see Figure 5-12), based on the approach described by Shields (1936) and including a conservative safety factor of 2 based on a review of the available shear stress data scatter (see Appendix D). Since the armor layer will serve as both erosion and bioturbation protection, a minimum thickness of 4 inches of 1.5-inch armor will be required to satisfy both requirements as shown in Table 5-3 for caps outside of the OU 4B federal navigation channel. Within the OU 4B channel, larger armor stone may be necessary to resist potential worst-case propeller wash, as discussed below.

- Ice scour – The design team retained the services of George Ashton, a national ice-expert retired from the USACE Cold Regions Research and Engineering Laboratory, to conduct an evaluation of the characteristics of ice formation on the Lower Fox River and the potential for these formations to create conditions favorable for ice-related scour of the river bottom or capping materials. A similar evaluation was previously conducted by Guenther Frankenstein (2003), another national ice expert. Both researchers completed a review of available historical climate data, conducted site visits, and conducted personal interviews with local individuals with significant experience on the river.

  Frazil ice is a group of individual ice crystals suspended in water that forms in super-cooled (slightly below 0°C), turbulent water. Frazil ice typically forms in rapids sections of rivers where there is turbulent mixing. In highly turbulent flows, frazil ice could be entrained in the flow beneath an overlying ice cover and has the potential to contact the bottom, where sediment particles could adhere to the individual ice particles, a process commonly referred to as "anchor ice". Both researchers concluded that the potential for formation of frazil ice is limited to the area immediately downstream of the Little Rapids and De Pere dams. No prospective capping areas have been proposed within the portions of OUs 3 and 4 that have a likelihood of forming frazil ice (and therefore anchor ice) or within the potential zone of frazil ice deposition [1.6 miles downstream of the Little Rapids Dam or 1,400 feet downstream of the De Pere dam] (see Appendix D).

  Ashton (2005) also estimated that a maximum of 1.5 to 2.0 feet of ice is expected to form at the Site for an average year and 2.0 to 2.7 feet during an extreme winter. In addition, a statistical analysis of maximum ice thickness (99th percentile; 1 percent probability of exceedance) and low water elevation (100-yr event) was performed to evaluate potential worst-case combined conditions. As discussed in Appendix D, this statistical analysis indicates that under these combined worst-case conditions, the elevation of the bottom of the ice formation may extend to elevation 584.9 and 573.6 ft IGLD85 for OUs 3 and 4, respectively. As discussed below, all engineered caps were design to have a maximum top elevation of 584.3 and 573.5 ft IGLD85 in OUs 3 and 4, respectively, to ensure long-term stability and performance.

- Wind-induced waves – The nearshore spectral wind wave model (Simulating Waves Nearshore [SWAN] software) was used to simulate wind-generated waves for various meteorological conditions (see Appendix D) for OUs 3 and 4. Bottom shear stresses resulting from four separate extreme wind-generated waves were predicted. The maximum predicted shear stresses from the wind waves in OUs 3 and 4 (less than 30 dynes/cm^2) were significantly less than the maximum predicted shear stresses discussed above during the reasonable worst-case hydrodynamic condition, confirming that wind-wave forces are less of a concern for cap design than flood and seiche forces.

- Vessel-induced propeller wash – Predictive equations were used to estimate the bottom velocity of several design vessels operating within the Fox River (USACE 1998a, Verhey 1983, Blaauw and van de Kaa, 1978). These predictive equations were developed for large (ocean-going) vessels in a maneuvering operation (i.e., mooring or un-mooring where vessel speed is essentially zero) and require adaptation to address smaller recreational vessels or moving conditions. Therefore, to ensure that cap designs are protective of potential propeller wash from smaller recreational vessels, a field study using bottom-mounted current meters to measure actual bottom velocities of maneuvering and passing vessels in the Fox River was conducted in October 2005. A preliminary evaluation of the field study results was used to verify the protectiveness of the cap armor layer designed in accordance with the USACE/EPA guidance, as discussed in Appendix D. More detailed analysis of the October 2005 data will be performed as part of the 30 Percent Design submittal to refine and optimize cap designs to ensure long-term stability and performance. Based on engineering evaluations performed for this BODR (see Appendix D), a median stone size of 1.5 inches (i.e., gravel; see Figure 5-12), will resist the reasonable worst-case hydrodynamic condition in all areas of OU 3 and 4. This armor stone will also resist erosion when subjected to the propeller wash of a range of characteristic vessels (e.g., *Foxy Lady* Tour boat or recreational boats) passing over an in situ cap under relatively shallow water conditions. All cap designs presented in this BODR include gravel or larger armor materials. As discussed in Appendix D, cap armor stone materials included in the Optimized Remedy cap designs will protect against all potential propwash conditions measured or modeled to date within the Fox River. As noted above, more detailed analysis of the October 2005 field study data will be performed as part of the 30 Percent Design submittal to refine and optimize cap designs to further ensure long-term stability and performance.

  For capping areas within the OU 4B federal navigation channel, where large cargo ships occasionally call on docks up to the Fort Howard turning basin, preliminary modeling indicates that a larger median stone size (6 to 9 inches; i.e., quarry spalls) should be used to ensure that cap erosion does not occur under anticipated worst-case conditions (see Figure 5-13). This armor stone size has been incorporated into the Optimized Remedy cap design as appropriate given the specific site conditions. These cap designs may be refinemed during later phases of design to ensure long-term stability and performance.

Operational Considerations. Given the inherent difficulties in achieving accurate placement tolerances for in-water construction, an additional thickness ("over-placement allowance") is typically specified in the capping contract. For the Lower Fox River the over-placement amount is expected to vary between 0 to 6 inches with an average of less than 3 inches for sand and gravel layers and an average of 6 inches for quarry spall armor layers. This is based on anticipated cap placement equipment (mechanical clamshell), experience at other similar capping projects, and considerations of likely contractor incentives to limit the amount of excess thickness. Therefore, for costing and

subsequent engineering evaluations, an additional 3 inches of sand cap material, 3 inches of gravel armor material, and 6 inches of quarry spall armor material (where applicable) have been assumed, as summarized in Table 5-3 and Figures 5-12 and 5-13. In accordance with workgroup discussions, specification language will be developed as part of future design submittals that will include the average over-placement allowance. As noted above, the mixed portion of the sand chemical isolation layer is conservatively assumed not to contribute to the chemical isolation thickness (T_i) of the cap (see Figure 5-12 and 5-13).

5.3.2 Additional Optimized Remedy Cap Design Considerations

In addition to designing the cap thickness as discussed above, the following other factors were considered in the design of the capping component of the Optimized Remedy:

- **Federal Navigation Channel in OU 4** – The horizontal extent of caps included in the Optimized Remedy were offset at least 10 feet horizontally from the lateral boundaries of the federal channel, while the top of the cap (with target overplacement allowance) was offset at least 2 feet below the vertical boundary of the navigation channel. The boundaries of the federal navigation channel in OU 4A were based on the reauthorization language included in the 2005 WRDA Bill approved by the House, and expected to be approved by the Senate (see Section 2.2.2.3). The horizontal and vertical offsets outlined above are commonly applied by the USACE to account for maintenance dredging tolerances, and have also been applied to other CERCLA contaminated sediment capping projects in similar navigation channel environments (see Appendix D).
- **Infrastructure and Utilities** – The practicability of performing remedial actions (dredging and/or capping) in close proximity to structures within the river will be considered on a case-by-case basis during later stages of design.
- **Geotechnical Stability Analysis –** Several geotechnical stability evaluations were conducted for the cap design, including the following (detailed design evaluations are presented in Appendix D):
    - **Bearing capacity of existing sediments -** A maximum cap layer thickness (i.e., critical height differential) of 10 to 12 inches that could be placed in a single application was calculated in general accordance with the EPA/Corps guidance (Palermo et al. 1998b), using three different methods: a deterministic evaluation, a probabilistic evaluation, and a comparison to past similar capping projects. Based on these calculations, and to minimize mixing of the cap into underlying sediments, a maximum 6-inch initial cap lift thickness was assumed during construction. Caps thicker than 6 inches will require multiple lifts, providing a consolidation period between lifts to increase bearing strength.
    - **Slope Stability -** Using geotechnical data collected during the RD investigation, the stability of caps placed on side slopes was evaluated. Based on these analyses, caps placed on slopes up to 2.75H:1V are predicted to be stable, with a factor of safety of 1.3 or better (calculated using the Slide computer software with sediment parameters determined from the RD investigations). The Optimized Remedy does not include caps installed on slopes steeper than 2.75H:1V. As discussed above, more detailed

evaluations of nearshore cap requirements will be included in subsequent design submittals (under either the ROD or Optimized Remedy).

- **Cap Punch Through Analysis** – Any shallow water caps (e.g., top of cap approximately 3 feet below the low water elevation) were designed to support the weight of an individual walking on the surface, consistent with USEPA and USACE cap design guidance (Palermo et al. 1998b). The cap designs included in the Optimized Remedy have a safety factor of at least 1.3 under this condition, and thus will be stable under worst-case bearing loads**.**

- **Ebullition –** Caps designed for inclusion in the Optimized Remedy also considered the potential for gas generation and its possible effect on cap stability. Based on the design analysis (summarized in Appendix D), sand and gravel materials incorporated into the cap design will dissipate any gas (e.g., methane) that may be produced in the underlying sediments. The design analysis did not identify gas ebullition as a short- or long-term pathway of potential concern that would affect performance of the cap system.
- **Post-Cap Water Depth –** As discussed in the RODs and summarized in Section 5.1.2, the Optimized Remedy does not include placement of engineered caps that would result in a cap surface elevation within 3 feet of the water surface, in order to:
  - Prevent potential damage from ice scour and wind/wave forces;
  - Allow for unencumbered recreational vessel traffic; and
  - Prevent the development of undesirable fish (e.g., carp) habitat.

The following water elevations were used in the design of the Optimized Remedy as it relates to post-cap water depth (i.e., the minimum 3-foot water depth required above the cap surface; Table 5-4) and hydrodynamic evaluations (discussed further in Appendix D).

Table 5-4. Summary Baseline Water Elevations

Operable Unit	Baseline Water Elevation Dynamic Height (IGLD85)	Basis for Selection
OU 2	593.5 feet	NOAA Low Water Datum above Little Kaukauna Dam
OU 3	587.3 feet	Crest of De Pere Dam (and NOAA Low Water Datum)
OU 4	576.5 feet	Lower 1% occurrence frequency of hourly summer data from NOAA gage at Green Bay (adjusted for long-term data record through 1953)

5.3.3 Capping Designs and Areas

The Optimized Remedy utilizes several different cap designs depending on location-specific conditions, as shown in Table 5-5 and Figures 5-12 and 5-13; the designs are described in more detail in Appendix D. Figures 5-5 and 5-6 present the mosaic of remedial actions included under the Optimized Remedy, and illustrate the approximate horizontal extent of areas subject to dredging, engineered capping, and hybrid dredge-and-cap combinations in OUs 3 and 4, respectively.

Table 5-5. Summary of Optimized Remedy Cap and Cover Designs

Cap Description [a]	Minimum Post-Remedy Water Depth (ft)	PCB Concentration in Existing 0 to 1.5-ft Interval	Area Proposed under Optimized Remedy [b] (acres)	Comments
13-inch Sand Cap with Gravel Armor	3 feet	< 10 ppm	400	Used in low concentration areas where mixing zone of clean sand provides necessary chemical isolation.
16-inch Sand Cap with Gravel Armor	3 feet	10-50 ppm	25	Used in areas where 3 inches of uncompromised chemical isolation layer is necessary for protection.
33-inch Sand/Quarry Spall Cap	3 feet	10-100 ppm	25	Used only in OU 4B navigation channel, where large cargo ships may potentially develop relatively high propwash forces, and in the vicinity of core location 4032-06; see Section 5.2.1.
Cover (6-inch)	N/A	<1 ppm except single sample with 1-2 ppm [c] or Dredge Residuals	210 [d]	Used to cover low risk areas and post-dredge residuals

Notes:

- Cap thicknesses above refer to the "target" thickness.
- Areas include potential capping in shoreline areas where dredging cannot be performed, as discussed in Section 5.1.
- See Section 5.4.
- Area includes cover only areas. Dredge residual cover areas to be determined during construction, but estimated to include approximately 440 acres.

5.3.4 Equipment Selection and Production Rates

Several types of equipment and cap placement techniques have been successfully implemented on numerous projects in recent years including the following:

- Direct placement with a mechanical clamshell bucket;
- Surface release from a barge or hopper;
- Spreading with hydraulic pipeline and baffle box or plate;
- Submerged diffuser or tremie; and
- Washing off barge with high powered jet.

Based on a review of site conditions on the Fox River, evaluation of capping projects performed in similar environments, and discussions with regional contractors, cap placement by mechanical clamshell bucket was determined to be most efficient means of construction. Import cap material (sand and gravel) will be delivered to a stockpile location in OU 4 (likely the Shell Property staging facility) by a large-capacity (approximately 20,000 ton) material vessel. The cap material will be offloaded from the delivery vessel and stockpiled at the Shell Property staging facility. The cap material will then be transferred, as needed, to smaller shallow draft barges by means of a hopper and conveyor system for transport to capping locations across the site. Due to the shallow depth over the sill at the De Pere lock system (6 feet), material barges for transport to OU 3 will be limited to approximately 500 ton (approximately 300 cy) capacity. Larger barges (1,000 ton – 600 cy) will operate in OU 4.

A front-end loader will likely be permanently stationed on the material transport barges to continually manage the stockpiles and feed the clamshell to increase production rate. For the purpose of this BODR, it was conservatively estimated that up to 10 percent of the material delivered to the site could be lost during offloading, stockpile management, barge loading, and other site operations. This potential for loss was accounted for in the project cost estimate (see Section 8).

As discussed above, cap placement will be performed using mechanical equipment, with a 5 cy clamshell bucket. The clamshell bucket will be equipped with a global positioning system (GPS) to ensure accurate cap placement within the limits defined on the construction plans. In addition, a floating grid or a GPS grid in the derrick cab will be positioned in front of the cap placing derrick to provide the operator a visual guide and means of confirming placement volumes (i.e. spreading of a given bucket volume over a constant grid area).

Based on USACE guidance (Palermo et al. 1998b) and discussions with regional contractors, the following assumptions were made in calculating an average production rates for capping:

- 5-cy mechanical clamshell bucket capacity;
- 75 percent bucket load efficiency;
- 50 and 60 percent "up-time" (OUs 3 and 4, respectively);
- Cycle time of 1.5 minutes; and
- Capping will be performed over two 12-hour shifts per day in OU 4. Given the relatively small amount of capping required in OU 3, a single 12-hour shift per day was assumed for OU 3 capping operations.

Based on these parameters, an average hourly production rate of 75 and 90 cy per hour is estimated for OUs 3 and 4, respectively. This production rate includes down-time associated with movement and repositioning of the derrick barge, as well as mechanical breakdowns and weather delays. These production rates have been used in the Optimized Remedy cost estimates (Section 8) and estimated construction schedule (Section 6).

5.4 Optimized Remedy – Sand Cover Design

The Optimized Remedy cover design includes placement of two 3-inch sand cover layers, to achieve a minimum cover thickness of 6 inches. Based on a review of sediment geotechnical characteristics in OUs 3 & 4 and considering sediment cap placement experience at other sediment sites with similarly soft sediments (e.g., Verduin and Lynch 2005), the first 3-inch lift of sand could mix partially or completely with the underlying sediment during placement. However, following a waiting time of at least several days to allow the initial layer of mixed sand/surface sediments to gain strength prior to placement of the second lift, the second cover lift (3-inches) can likely be placed without any substantive mixing into underlying sediments. Calculated post-cover surface sediment

and prospective SWAC concentrations (see Section 5.6 below) were based on this two-layer sand placement design.

Based on new remedial design information collected during 2004 and 2005, a substantial area of OUs 2 to 5 contains a veneer (up to 6-inch) of sediments with PCB concentrations marginally above the 1 ppm RAL, generally described as shallow "bench" areas in Section 2.3. These surficial sediments, which contain maximum PCB concentrations of up to 2 ppm, overlie cleaner sediments with PCB concentrations well below 1 ppm. Additional sediment areas within OUs 2 to 5 contain a similarly thin (6-inch) subsurface layer of sediment with concentrations between 1 and 2 ppm underlying an existing surface layer of sediment with concentrations below the 1 ppm RAL.

Because of the limitations and tolerances of typical dredging equipment, as discussed above, attempts to remove these thin sediment deposits would result in removal and disposal of a much greater volume of non-target sediments containing PCB concentrations less than the 1 ppm RAL. Furthermore, these areas cumulatively represent only about 0.5 percent of the total PCB mass in OUs 2 to 5, and pose relatively minor human health and environmental risks.

Therefore, the Optimized Remedy includes placement of 6-inch sand covers to address low risk deposits that have the following characteristics:

- Maximum PCB concentration no greater than 2 ppm in any core sample interval
- Maximum of one sampled interval (6 inch thickness of sediment) in the core with concentrations exceeding the 1 ppm RAL
- All other sediment in the core equal to or less than the 1 ppm RAL

Approximately 210 acres in OUs 2 to 5 meet the general criteria summarized above and are therefore suitable for cover with a 6-inch-thick layer of sand (Table 5-6). These 210 acres contain approximately 400,000 cy of sediment that would otherwise be dredged under the ROD Remedy. In the majority of the cores collected within this area as part of the RD investigations (105 of 119 total cores) the surface sample (collected over the 0 to 4 inch interval below the existing mudline) was the only interval in the core that contained PCB concentrations above the 1 ppm RAL. In the remaining 14 cores, the PCB concentration in the surface samples was below the RAL, but the concentration in a single 6-inch shallow subsurface sample interval contained PCB concentrations between 1 and 2 ppm.

Future analysis during RD may identify other localized areas that are inappropriate for dredging or engineered armored caps, but appropriate for sand covers, based on the presence of relatively low PCB concentrations and thicknesses, or due to particular implementability, practicality, or engineering feasibility concerns at specific locations.

Table 5-6. Mass and Volume Estimates for Optimized Remedy Actions

Remedial Action	Volume[a]		Mass Removed [b]		Area		
	[cy]	[% of OU 2-5 Total]	[kg]	[% of ROD Total]	Area of Remedial Action [acres]	[% of OU 2-5 Total]	[% of 1 ppm footprint]
Dredge to 1 ppm	3,500,000	48%	10,500	54%	510	22%	44%
Dredge & Cap	1,200,000	17%	3,900	20%	115	5%	10%
Engineered Caps	2,100,000	29%	0	0%	335	15%	28%
Sand Covers [c]	400,000	6%	0	0%	210	9%	18%
No Action	0	0%	0	0%	1,120	49%	0%
Total	7,200,000	100%	14,400	74%	2,290	100%	100%

- Includes volume of sediment with PCB concentrations exceeding 1 ppm addressed by respective remedial actions.
- Excludes post-dredge residual contamination.
- Includes 6-inch sand cover over low risk sediment deposits with a maximum 6-inch thickness of sediment between 1 and 2 ppm. Does not include post-dredge residual cap areas

Figures 5-5 and 5-6 present the approximate horizontal extent of areas targeted to receive a 6-inch sand cover in OUs 3 and 4, respectively. Areas with a final depth of water above the constructed cover of less than 3 feet (relative to low water datum) are differentiated from those areas with greater than 3 feet.

Hydrodynamic evaluations (described in more detail in the Appendix D) suggest that sand covers placed in locations depicted on Figures 5-5 and 5-6 will maintain their integrity over time, with little or no mixing into the underlying sediments or erosion due to river flows. For example, sand-sized particles are predicted to be stable over the majority of the river bottom even under a 100-year design flow event.

As an additional evaluation of the limited benefit associated with removal of these “low mass” sediments and the diminishing mass reduction benefits, cumulative plots were prepared of the PCB mass removed under the ROD Remedy ranked in order of decreasing mass per unit area (MPA) of individual sediment areas. As shown on Figure 5-18, the range of MPA associated with the approximately 210 acres of proposed sand covers represents a small portion of the cumulative mass that would be removed under the ROD Remedy. The calculation method used to calculate the MPA is presented in Appendix A.

5.5 Water Depth and Hydrodynamic Considerations

The bathymetry within the river will change as a result of the dredging, capping, and cover placement associated with the Optimized Remedy. This section presents an evaluation of the various changes expected as a result of implementation of the Optimized Remedy, to support a further assessment of the long-term effectiveness of this remedy.

5.5.1 Bathymetric Changes Resulting from the Optimized Remedy

As discussed in Section 5.3.1 above, Figures 5-14 and 5-15 present the changes in water depth from existing conditions following completion of the Optimized Remedy for OUs 2/3 and 4/5, respectively. Within OU 3, the Optimized Remedy includes an approximate balance of dredge and cap/cover volumes, such that there is no net change in the total area at various water depths (Figure 5-14). However, given the considerably greater dredge versus cap/cover volume in OU 4, the result of the Optimized Remedy is to provide a net deepening of the reach, as shown on Figure 5-15.

5.5.2 Navigation and Recreational Use Impacts

The Optimized Remedy was designed with consideration of both recreational and commercial navigation within the federal navigation channel in OU 4, including the reauthorized OU 4A channel. An appropriate offset has been maintained beyond the horizontal and vertical limits of the navigation channel (consistent with other completed Superfund projects) to ensure safe navigation as well as protection of the in situ caps.

The Optimized Remedy design also considered the frequent use of the river for recreation purposes. As discussed in Section 5.3.2 and Appendix D, in addition to removal of PCB mass, a significant consideration in designing the Optimized Remedy was maintaining a minimum post-cap water depth of 3 feet. This minimum post-cap water depth was partly based on the goal of maintaining existing recreational use of the river. To achieve this goal in relatively shallow areas, dredging was incorporated into the Optimized Remedy in many sections of the river. Furthermore, the baseline water elevation used to measure post-remedy water depth was selected based on a review of long-term historical records including extended periods of low water in the mid 1960s. The baseline water elevation used in the evaluations corresponds to a reasonable worst-case 1 percent frequency event. That is, the water depth over the cap areas in OU 4 will be greater than 3 feet in more than 99 percent of the boating season conditions that have been measured over the period of record (see Appendix D).

5.5.3 Aquatic Habitat Functional Changes

The minimum post-cap water depth discussed above was also selected in part to prevent remedy-induced impacts to fish habitat. Making the river shallower is perceived to have a negative impact on the aquatic system (WDNR 2005). Shallow water provides limited habitat for the species considered desirable by anglers. WDNR fish managers prefer that existing depths greater than 8 feet be maintained after implementation of the Optimized Remedy, to avoid these potential adverse impacts. Figures 5-14 and 5-15 illustrate that, overall, the Optimized Remedy does not create any more shallow-water habitat than currently exists. Within OU 4, the Optimized Remedy will provide additional deeper habitat, which will provide fisheries benefits.

5.5.4 Hydrodynamic Modifications

As discussed in the ROD, the remedy for the Lower Fox River must comply with the substantive provisions of WI Statutes Chapter 30 and the federal Rivers and Harbors Act of 1899, 22 CFR 403. Under Chapter 116 of the Wisconsin Administrative Code, the remedy must not adversely alter the 100-year flood plain for the river. As suggested by WDNR and EPA, initially a volume balance approach was used to evaluate potential changes in the flood plain as a result of remedial action. Because dredging volumes are substantially greater than capping volumes in OU 4 (see Figure 5-15), the 100-year flood plain in OU 4 is not expected to be adversely impacted by the Optimized Remedy.

In OU 3, the volume of material to be removed under the Optimized Remedy (approximately 204,000 cy) is slightly less than the proposed cap and cover volume (approximately 260,000 cy, excluding cap consolidation, which will reduce the net placement volume) indicating that the river will be marginally constricted as a result of the Optimized Remedy (see Figure 5-14). To further evaluate the potential for remedy-related water level increases during the 100-year flood condition, the OU 3 hydrodynamic model (Appendix D) was applied to post-remedy bathymetric conditions. The hydrodynamic analysis did not identify any potential for significant water level changes resulting from the Optimized Remedy, within the approximate 0.05-foot accuracy of the model inputs.

The results of the hydrodynamic model for post-remedy bathymetric conditions indicates that all of the remedial action areas included in the Optimized Remedy, including capped areas, are expected to be stable, with little potential for long-term erosion from natural or anthropogenic forces. Capped areas have generally been identified as net depositional environments under typical flow events and have been designed appropriately to resist erosion even under the design flow condition (e.g., 100-year flood and worst-case seiche event). The characterization of these areas (and the majority of the river) as net depositional areas are further corroborated by the following lines of evidence:

- The continued, and relatively frequent dredging by the USACE to maintain the OU 4B channel and turning basins;
- The deposition of 4 to 5 feet of sediments above the SMU 56/57 cover observed over the 5-year period following construction (see Figure 5-11); and
- Radioisotope analyses of cores collected throughout OUs 3 and 4 during the RI/FS that demonstrate a relatively constant sedimentation rate of 1 to 2 cm/year, with little or no mixing evident below the surficial (0 to 10 cm) bioturbation zone.

Plan-view maps of anticipated net changes in bed elevations resulting from implementation of the Optimized Remedy are presented in Figures 5-19 and 5-20 for OU 3 and OU 4, respectively.

5.6 Post-Optimized Remedy SWAC Estimates

As discussed in Section 3.6.4, in all environmental dredging operations completed to date, a relatively small fraction (typically ranging from 2 to 8 percent, and averaging 5 percent) of the sediment and

contaminant mass targeted for removal has been observed to settle back onto or immediately adjacent to the dredge area. Best management practices (BMPs) will be developed as part of the RD specifications to minimize the magnitude of residual contamination (e.g., specifying use of precise real-time positioning and monitoring systems, control of vessel draft and movement, and reducing cut slope sloughing). However, even under the most optimistic scenario (i.e., 2 percent mass loss), management of dredge residuals will be needed after completion of dredging in order to meet the SWAC targets. The sensitivity of the SWAC to variations in the percent mass loss (and other variables) is currently being discussed with the Technical Workgroup and will be presented under separate cover from this BODR.

The approximate range of the post-dredge SWAC in OUs 3 and 4 can be estimated using the 2004 and 2005 RD sampling data and Optimized Remedy dredge plan design developed to date for this BODR, and based on a "best estimate" of 5 percent mass release, consistent with the average residual reported to date from similar dredging projects (see Section 3.6.4). As discussed in more detail in Section 7, prospective SWAC calculations were based on the assumption that sediment concentrations in no action areas (i.e., areas with measured PCB concentrations at or below the 1 ppm RAL) are equivalent to the concentrations measured during the 2004 and 2005 RD investigations, and that post-remedy concentrations in engineered cap areas are zero.

The post-placement surface (0 to 10 cm [0 to 4 inches]) cover concentration can be estimated by calculating the density-weighted average PCB concentration over the top 4 inches of the cover, assuming complete mixing of the first 3-inch lift with the top 3 inches of the existing surface sediment, but no mixing of the second 3-inch cover lift (see Figure 5-12). Average dry densities for commercially available sand and in situ (uncompacted) surface sediments in OU 3 and OU 4 are approximately 1.5 gms/cm^3 and 0.45 gms/cm^3, respectively. Using these sediment densities and the mixing assumptions outlined above, the post-residual cover SWAC can be estimated as summarized in Table 5-7.

Table 5-7. Estimated ROD and Optimized Remedy SWAC

Operable Unit	Existing SWAC [ppm]	ROD Remedy SWAC		Optimized Remedy SWAC	
		No Residuals Management [ppm]	Covers Placed Above 1 ppm and Mixing of Lower 3" of Cover [ppm]	No Residuals Management [ppm]	Covers Placed Above 1 ppm and Mixing of Lower 3" of Cover [ppm]
OU 3	2.0	0.57	0.31	0.49	0.28
OU 4/5	3.2	3.7	0.32	2.9	0.25

Without dredge residual management and assuming 5 percent mass release and other most likely (i.e., median) predicted post-dredge and post-cover characteristics, the Optimized Remedy estimates of the post-dredge SWAC in OUs 3 and 4 are approximately 0.49 ppm and 2.9 ppm, respectively, exceeding the ROD targets of 0.26 ppm and 0.25 ppm (Table 5-7). The frequency distributions of estimated

post-dredge residual surface concentrations anticipated under the Optimized Remedy are summarized in Table 5-8, and reveal that in most dredge areas (i.e., in more than 300 dredging acres) post-dredge residual concentrations are expected to range between roughly 1 and 10 ppm. Like the ROD Remedy (see Section 3.6.4.2), these calculations underscore the need for effective dredge residual management.

Table 5-8. – Summary of Anticipated Post-Dredge Residual Concentrations

Optimized Remedy Estimated Post-Dredge Surface PCB Concentration [ppm]	OU 2/3 Area [acres]	OU 4/5 Area [acres]	Average Post-Cover Surface PCB Concentration [ppm]
<1	24	93	N/A
1-5	39	182	0.21
5-10	12	105	0.41
10-20	2	69	0.82
20-30	0	17	1.2
30-40	0	9	1.6
40-50	0	0	N/A
>50	0	4	2.5

Placement of a 6-inch sand cover (in two 3-inch lifts; see Section 5.4) is expected to reduce the post-construction SWAC in OUs 3 and 4 to approximately 0.28 ppm and 0.25 ppm, respectively (Table 5-7). The Table 5-7 summary also reveals that the Optimized Remedy will likely attain a lower post-construction SWAC than the ROD Remedy. Again, the sensitivity of the SWAC to variations in key variables, and associated adaptive management provisions, is being discussed with the Technical Workgroup to help ensure that the SWAC targets specified in the ROD are achieved at the completion of construction.

5.6.1 Dredge Residual and Undredged Inventory Management

The following management options for dredge residuals above the RAL and for potential undredged inventory are available and will be evaluated during later phases of the design:

A. Placement of post-dredge residual covers;

B. Placement of engineered armored caps;

C. Cleanup pass dredging; and/or

D. Adaptive management using these and other options, as appropriate.

Residuals Covers and Engineered Caps. Sand covers are identified as the most likely dredge residual management strategy, where appropriate for the individual location. In those areas where sand covers may not be sufficiently protective, but where the permanent stability and performance of

engineered caps can be assured, and where further dredging would not be expected to provide additional PCB mass removal or risk reduction, the Optimized Remedy includes engineered caps, consistent with the contingent remedy provisions of the ROD. Engineered cap designs are presented in Section 5.3 and in Appendix D.

For those areas where sand covers are sufficiently protective, sand covers would be placed on the post-dredge surface in two successive 3-inch lifts, with a waiting time between lifts to allow the mixed sand/surface sediments to gain strength. If covers are placed on all post-dredge residual areas exceeding 1 ppm, the most likely (i.e., median estimate) post-construction SWACs in OUs 3 and 4 will be reduced to approximately 0.28 ppm and 0.25 ppm, respectively (Table 5-7; assuming mixing of the lower 3 inches of the cover). Similar to the MNR option summarized above, surface concentrations in certain cover areas could be monitored over time as needed to demonstrate that the SWAC is met throughout OUs 3 and 4 at the completion of remedial actions. More detailed analyses of covers as a post-dredge residual management option, and associated adaptive management plans, will be developed during the 30 and 60 Percent Design submittals.

Cleanup Pass Dredging. Based on the results of initial engineering evaluations, cleanup pass dredging is currently envisioned in areas where remaining inventory of sediments greater than the 1 ppm RAL is observed following completion of dredging to the specified elevation, and where engineered capping or sand covers are not judged acceptable. In addition, cleanup pass dredging of certain post-dredge residual deposits may be considered where the physical conditions in the specific dredge management area suggest that an additional dredge pass would be effective and is environmentally warranted. Further engineering refinements will be conducted as part of the 30 Percent Design submittal and will include a detailed evaluation of the anticipated in situ solids concentration appropriate for redredging and resulting impacts on both dredging and mechanical dewatering process efficiencies.

Adaptive Management. Management of dredge residuals may require a combination of the options outlined above, as well as other options as appropriate, informed by the results of post-dredge sampling and analysis data. For example, dredging will create a deeper elevation surface, compared to the current river condition, that will likely accumulate recent sediments at a more rapid rate than existing conditions. Enhanced sedimentation rates in the post-dredge area was observed in the five years following completion of the SMU 56/57 demonstration project, where sedimentation rates during this period ranged between approximately 20 and 30 cm/year. Adaptive management of dredge residuals may consider this condition. More detailed analysis of residual adaptive management options will be developed during the 30 and 60 Percent Design submittals.

5.7 Monitoring, Maintenance, and Institutional Controls for Capping

The Optimized Remedy includes in situ caps designed to be protective of human health and the environment in perpetuity. The design of the caps discussed above includes consideration of all relevant site conditions (erosive forces, groundwater flow, etc.) and incorporates conservative factors of safety to ensure stability of the caps and containment of underlying contaminated sediments in perpetuity. The hydrodynamic modeling results presented in Sections 5.3 and 5.4 demonstrate that areas of capping under the Optimized Remedy are predicted to be stable over the long-term. A long-term monitoring, maintenance, and adaptive management plan will be developed through technical Workgroup discussion to verify and/or ensure long-term performance of the capped area. This plan will be formally presented during later stages of the design (at the 60 Percent Design Submittal), but is generally outlined in this section and Section 7, with estimated costs presented in Section 8.

As discussed in the ROD (see Section 5.1.2) and the Remedial Design Work Plan, institutional controls unique to capping will be implemented as part of the Optimized Remedy to ensure the integrity and protectiveness of capped areas. Potential institutional controls will be identified and evaluated in an institutional control plan that will be part of the long-term monitoring, maintenance, and adaptive management plan described above. The institutional control plan will set out the institutional controls that are necessary to ensure the integrity of capped areas.

The ROD, along with White Paper 6B, identifies several potential institutional controls that could be required. These controls include restrictions on dredging and anchoring in capped areas. The ROD and White Paper 6B also include discussion of the possible effects of dam removal on integrity of the cap. The institutional control plan will include all of these potential institutional controls in its evaluation.

In order for an institutional control to be required, the control must be necessary to ensure the long-term protection of human health and the environment in light of reasonably anticipated circumstances. For example, given the ownership and regular inspection and maintenance of the De Pere dam by the U.S. Army Corps of Engineers, no basis currently exists to anticipate that this dam will fail or be removed. Nevertheless, if the De Pere dam were removed in the future, soft sediment deposits in OU 3 upstream of the dam may be subject to erosion and transport. The degree to which OU 3 sediment would be transported downstream depends on the manner in which the dam might be removed. The most likely scenario is that the dam would be removed in a controlled manner; if so, little or no sediment would be transported downstream. However, although detailed hydrodynamic analyses have not been performed, even if dam removal caused a wholesale movement of sediment, the average PCB concentration of that sediment would likely be low. Under the Optimized Remedy, approximately 2.0 million cy of recent (post-dam) soft sediments would be retained in OU 3 after remedy construction, along with a relatively small amount (0.2 million cy) of sediment cap material. These sediments would contain an average PCB concentration of about 0.4 ppm, well below the RAL

of 1 ppm. As a result, institutional controls to prevent the removal of De Pere dam are unlikely to be necessary to ensure the long-term protection of human health or the environment. (In comparison, under the ROD Remedy, about 1.6 million cy of soft sediment would remain in OU 3, at an average PCB concentration of approximately 0.2 ppm. Erosion of this material if the De Pere dam were removed would also not endanger human health or the environment.)

In addition, an institutional control may be deemed to be in place already if another agency has responsibility for conducting an activity or enforcing a prohibition and existing laws or regulations require an environmental review before that program is changed. For example, the institutional control evaluation will examine existing U.S. Army Corps of Engineers responsibilities related to operation and maintenance of the De Pere dam as part of the Fox River Navigational System. White Paper 4, issued along with the ROD, describes Wisconsin regulatory and environmental review requirements associated with proposals for dam removal. White Paper 4 also notes that the USACE has continued to operate, inspect, and maintain the De Pere dam. The institutional control evaluation will also consider the implications of the De Pere dam's listing on the National Register of Historic Places and the considerable amount of infrastructure and recent residential development along OU 3 that depends on continued operation of the dam.

Other prohibitions may exist already, and the Institutional Control Plan will consider whether those prohibitions are effective institutional controls or whether an intergovernmental agreement is needed to confirm their long-term effectiveness. For example, the U.S. Coast Guard already enforces appropriate restrictions on anchoring or dredging within and/or beneath the navigation channel, and these restrictions are expected to continue in perpetuity as part of channel operations. In addition, the Optimized Remedy design minimizes capping beneath the navigation channel in OU 4B, except in a few areas where sediment contaminants are deeply buried and relatively unsuitable for dredging (see Section 5.1.1 and Figure 5-6). Moreover, cap armor designs included in the Optimized Remedy are capable of resisting worst-case propeller wash forces and foot traffic (see Appendix D), and the designs are also expected to maintain their integrity during anchoring operations. The institutional control evaluation will also examine the need for no-anchor zones outside the navigation channel. A focus of that evaluation will be to assess the expected rate of anchoring in the absence of no-anchor zones and determine whether, given the proposed frequency of monitoring, anchoring can be expected to pose a risk to human health or the environment. In addition, if no-anchor zones are determined to be necessary, the RD will evaluate and make recommendations on the details of no-anchor zones, including identification of areas requiring no-anchor zones and how they would be marked, and enforced.

As discussed above, long-term monitoring and maintenance will be performed to ensure the physical integrity of the cap and the permanent containment of the underlying sediment contaminants. Monitoring events will occur at a pre-determined schedule, with a combination of frequent

monitoring of target areas and periodic monitoring of other capped areas integrated into the overall program. Monitoring may be keyed to relatively large storm events (e.g., 50-year storms), and may also be triggered by other potential occurrences such as water levels below the long-term low-water elevation (see Table 5-4). Monitoring and maintenance plans associated with the Optimized Remedy are discussed in Section 7, and will be developed in more detail as part of the Intermediate (60 Percent) Design Submittal. The cost of the monitoring and maintenance program described in Section 7 has been included in the project costs estimate presented in Section 8

5.8 Optimized Remedy – Materials Handling, Transport and Disposal

This section builds on the review of materials handling, transport, and disposal options for the ROD Remedy presented in Sections 3 and 4, and identifies options that are applicable for the lower sediment dredging volumes and other characteristics of the Optimized Remedy (see Table 5-2). One of the more important differences between the two remedies, discussed in more detail below, is that a greater range of potential disposal options are available under the Optimized Remedy, including the following options:

- Pipeline transport to an NR 213 settling basin followed by separate landfill disposal (this is the same prospective disposal option identified for the ROD Remedy, but at a lower dredge slurry and disposal volume);
- Pipeline transport of sediment slurry directly to a dewatering landfill, where passive dewatering will occur (this option was considered and evaluated for the ROD Remedy, discussed in Section 4, but was not identified as an implementable option because of the relatively large disposal volumes associated with the ROD Remedy); and
- Mechanical dewatering of sediment at the staging facility, followed by trucking of the sediment to a regional landfill.

This broader range of potential disposal options is outlined in the section below. Other materials handling, transport, and disposal considerations relevant to the Optimized Remedy are also discussed.

5.8.1 Initial Water Transport of Debris and Dredged Material

As described above, large debris from within the dredge area will be removed and transported by barge to the staging area (described in Section 5.8.5), and offloaded using mechanical equipment. The hydraulically removed dredge material (dredge slurry) from OUs 3 and 4 will be transported through a HDPE floating pipeline system to an in-water floating booster pump station which, in turn, will pump the slurry to the land-based dewatering facility (described in Section 5.8.3)at the upland staging area. The mechanically removed dredge material from OU 2 (24,000 cy), and nearshore areas of OU 3 (approximately 6,000 cy), will be transported by barge to the staging area berth. This barged sediment will have sufficient makeup water added to produce dredge slurry comparable to the

hydraulically dredged material. Using a high solids pump, the resultant dredge slurry will be pumped to the land-based desanding facility at the upland staging area.

5.8.2 Potential Offloading Procedures

Offloading of large debris will be facilitated using a land-based crane with rehandling bucket. Dredge slurry will discharge directly into double-deck grizzly screen equipment. This is the first stage of the land-based dewatering facility, removing coarse material and small debris, as further described below.

5.8.3 Potential Dewatering Options

As previously stated in the beginning of this section, there were three potential dewatering options identified and evaluated for the Optimized Remedy:

- Pipeline transport to an NR 213 settling basin and separate landfill.
- Pipeline transport of sediment slurry directly to a dewatering landfill.
- Mechanical dewatering of sediment at the staging facility, followed by trucking of the sediment to a regional landfill.

The first option, pipeline transport to an NR 213 setting basin with rehandling of "dry" material to a separate landfill, was evaluated based on the reduced dredge volumes in the Optimized Remedy. The results of this evaluation showed an increased difficulty in implementation and significantly higher cost when compared to the other two options. A description of the disposal evaluation associated with this option is in Section 5.8.7.2.

The second option, pipeline transport and sediment slurry deposited directly into a dewatering landfill, was evaluated under both the ROD Remedy and the Optimized Remedy for efficiency, implementability and value. As discussed in Section 4.1, the larger volume of dredge material in the ROD Remedy made this option non-implementable, due to a lack of available land space. However, for the Optimized Remedy this option is a viable alternative to the preferred option of mechanical dewatering, and as such, will be further evaluated during the 30 Percent Design phase. In the dewatering landfill concept, all material would be transported through a pipeline to a landfill for both dewatering and disposal of the desanded material. A description of the disposal evaluation associated with this option is provided in Section 5.8.7.2.

The preferred option for the Optimized Remedy, both in efficiency and cost effectiveness, is mechanical dewatering of the incoming dredge slurry, as depicted with the process flow diagram on Figure 5-21. Under this option, the dredge and booster pump(s) transport dredge slurry from the river to a dewatering facility at the staging area. The incoming slurry will initially enter double-deck

grizzly screens to remove coarse material and debris. The dredge slurry will then be directed through a vibratory wash screen (larger than the U.S. No. 200 sieve or 0.0029 inches) and spiral washer, followed by attrition scrubbers. This will liberate sand fractions from PCB-contaminated fractions. The attrition-scrubbed sand fraction will then be processed through traditional floatation technology (e.g. DAF) for removal of remaining humic matter, then through a hydrocyclone and dewatering screens to separate out the sand (less than 1 ppm PCBs). This resultant sand fraction will be slated for beneficial use (described in Section 4.3). A front-end loader (or other earth moving equipment) will then be used to move the sand to the designated on-site storage area. Figure 5-22 presents a mass balance of the sediment and water processed with the equipment proposed for use under the Optimized Remedy.

The remaining slurry consisting of PCB-contaminated fractions, fines (finer than the No. 200 sieve) and humic material will be pumped to multiple 20,000-gallon agitated mix tanks. Polymer will be added to the slurry as it is pumped from the mix tanks to plate and frame mechanical filter presses. Plate and frame mechanical filter presses were chosen in order to process the sediment into a "filter cake solid" that meets landfill specifications of 50 to 55 percent solids (by weight), with a compressive strength of at least 0.4 tons per square foot. After the appropriate "cycle time" is reached within the filter presses for the sediment to meet specifications, the "dried" sediment will be discharged onto a conveyor system that extends from the back of the press. A front-end loader will be used to move the filter cake to the designated on-site storage area. Figures 5-21 and 5-23 illustrate the overall process schematic and dewatering operation layout. The layout and number of dewatering units incorporated into the Optimized Remedy was developed to accommodate the approximate 3,200 cy/day production rate of a single 12-inch hydraulic dredge (see Table 5-9). The cycle times, or production rates, were calculated based on an incoming dredge slurry rate of 5,000 gpm, and a maximum solids concentration, to represent the worst case dewatering scenario. As discussed in Section 5.2.3, the dredging and dewatering operations have been designed as separate equipment trains with their own production and efficiencies. The dewatering operation is sized to handle the dredge running at full production. As such, redundancy is built in to prevent the dewatering operation from effecting the productivity (or efficiency) of the dredge operation.

Resultant effluent from the above dewatering process will be pumped to the water treatment system, outlined in the next section.

5.8.4 Water Treatment Options

The water treatment system will be designed and installed to adequately treat the required volumes of water (approximately 5,000 gpm, 7.2 MGD) generated during dredging, sediment dewatering, and decontamination operations. The water treatment system will also treat all precipitation that comes into contact with the asphalt work pads.

The water treatment system will consist of two untreated water surge tanks (approximately 250,000 gallon capacity each) followed by sand filters, carbon absorption units and bag filters. Treated water will be sampled to verify compliance with discharge requirements (see Section 7 for a summary of the general monitoring plan), and then discharged back to the Fox River through a submerged outfall in accordance with State of Wisconsin water quality requirements (see Section 4.1.2.4). Figures 5-23 and 5-24 illustrate the dewatering/water treatment facility layout and the overall water treatment process schematic, which is similar to the process used during the SMU 56/57 project (Foth & Van Dyke et al. 2001).

5.8.5 Staging Area Requirements

The Optimized Remedy will require an upland staging area(s) to offload debris and stockpile clean sand and gravel for residuals management and capping. Desanding and dewatering operations will also take place at the site, requiring sufficient space for desanding equipment, mechanical plate and frame presses for dewatering, water collection and treatment systems, and stockpile areas for sand collected from the desanding operation. In addition, the upland staging area can be used by the contractor for equipment storage, and will provide the location for the field office.

The upland staging area will require water access and sufficient berthing depth and length to accommodate floating equipment used for the remedial action. Debris will be transported by barge to the staging area, and will be offloaded using mechanical equipment (e.g., land-based crane with rehandling bucket). Sand supply vessels (e.g., barges or bulk cargo ships) will also need sufficient water depth and berthing length along a dock to tie up and offload.

A suitable staging area will provide the contractor with the following features:

- Sufficient acreage of upland for desanding/dewatering/water treatment processes, stockpile, equipment storage, and transfer facilities
- Adequate accessibility for truck access to haul routes.
- Minimum of 600 feet of dock face to allow tie up of two barges, end-to-end or sand supply vessel and one barge.
- Approximately 15 to 19.5 feet of water depth to accommodate moderate draft vessels.
- Surface area capable of supporting heavy equipment.

These criteria are similar to those required for the ROD Remedy, but due to the anticipated use of mechanical dewatering processes the required “footprint” is considerably larger. As discussed in Section 3.7, there are no sites in OU 3 or OU 4 that currently meet all of the key criteria. The Shell Property meets many of the key criteria, and has been identified as the most promising staging site for the ROD Remedy. The Shell Property has similarly been identified as the most promising staging

site for the Optimized Remedy. The same general site improvements discussed in Section 3.7 will be made at the Shell Property for the Optimized Remedy, with a few modifications as discussed below.

Under the Optimized Remedy, the existing shoreline offshore of the Shell Property will be improved to generally match the shoreline of the adjacent northern property, creating a wharf area with better approach and berthing area functions (Figure 3-11). The larger wharf area will involve filling and conversion to uplands of approximately 5 acres of OU 4, roughly 4 acres more than will occur under the ROD Remedy (Section 3.7). The total length of the sheetpile wall will be approximately 1,500 feet, with 750 feet accessible for berthing along the face. This configuration will fully meet the staging area criteria outlined above. The shoreline will be extended out from the existing shoreline by approximately 250 feet to provide safer access for berthing, concurrently increasing the upland acreage to approximately 27 acres. The backfill volume will be approximately 150,000 cy, assuming a top of bank elevation of approximately 585 feet IGLD 85. This upland backfill could be provided by using appropriate on-site "borrow" material and a portion of the separated sand (less than 1 ppm PCBs) from the desanding process.

Similar to the ROD Remedy, dredging offshore of the sheetpile wall will be sequenced relatively early during the Optimized Remedy, providing 15 to 19.5 feet of water depth (i.e., roughly elevation 562.5 to 558 feet IGLD 85). While approximately 20,000 cy of sediment potentially subject to TSCA disposal requirements will be removed from within the sheetpile area as a part of initial site development (equivalent to the amount of prospective TSCA removal in this area that will occur under the ROD Remedy), more deeply buried underlying contaminated sediment with lower PCB concentrations will be contained in place below the improved staging area fill. Historical shoreline filling actions that occurred during the 1960s and 1970s in this area of OU 4 have similarly contained PCBs below the adjacent uplands. Because of the presence of considerable debris and other piling in this area, removal of such deeper sediment under the ROD Remedy will be difficult and associated with relatively greater water quality and dredge residual impacts. These impacts will be obviated under the Optimized Remedy by installing the sheetpile wall prior to dredging of sediments potentially subject to TSCA disposal requirements, and by using containment/fill technologies to address the remaining, more deeply buried contaminants.

5.8.6 Beneficial Use Considerations for the Optimized Remedy

Alternatives for beneficial use of the sand portion of the sediment removed from OU 3 and 4 as part of the ROD Remedy are described in Section 4.5. For the Optimized Remedy, the difference is that all of the non-TSCA hydraulically dredged material in OU 3 and 4 would be desanded, resulting in a total of approximately 225,000 cy of segregated sand potentially available for beneficial use.

The same alternatives for the ROD Remedy, as described in Section 4.3, are potential options for beneficial use under the Optimized Remedy. These alternatives would be evaluated by the same process as described in Section 4.6.

Under the Optimized Remedy it is assumed that approximately 150,000 cy of the segregated sand removed would be used to restore on-site borrow pits from which material would be obtained to fill in behind a sheet pile wall constructed as the offloading dock at the Shell Property, as described in Section 5.8.5.

Several other beneficial use alternatives described in Section 4.5 could accommodate all or some of the remaining 75,000 cy of segregated sand available under the Optimized Remedy including use as daily landfill cover, roadway cover, and/or incorporation of suitable sand materials in range of potential beneficial use applications (see Section 4.3).

Any alternative for beneficial use will consider the temporary storage needs of segregated sand so as to match the rate of generation with the rate of use. Since discussions of beneficial use are in the preliminary stages, these types of design considerations will have to be considered at later stages of the project, once the beneficial use alternative(s) are selected.

5.8.7 Most Promising Transport and Disposal Options

The Optimized Remedy allows more flexibility for sediment transport and disposal that the ROD Remedy, due to a significant reduction in the amount of material to be landfilled. Table 5-2 presents the Optimized Remedy sediment disposal requirements. Depending on the final option selected, the Optimized Remedy will likely require approximately 1.476 million cy of non-TSCA landfill disposal capacity and 112,000 cy of TSCA landfill disposal capacity (these volumes refer to volumes after dewatering, and are based on the prospective option of mechanical dewatering at the staging facility, followed by trucking of the sediment to a regional landfill, as discussed below).

Based on conventional monofill characteristics for low strength solids material (such as paper mill sludge or sediments, the typical acreage requirement for disposal of this non-TSCA volume of material is 30 to 40 acres with an average fill height of 35 to 45 feet. Greater fill depths are possible, provided adequate engineering measures are taken. As shown in Tables 4-8 and 4-9, each of the three sites presented in Table 4-9 has adequate permitted or proposed acreage to accommodate all of the Optimized Remedy dewatered sediment volume. Additional operational considerations may need to be addressed in subsequent design phases for sizing of a dewatering landfill facility (see section 5.8.7.2).

Implementability considerations (technical and community acceptance), and the economics of pipeline construction and operating cost play a major role in the overall selection of transport and

disposal alternatives for the Optimized Remedy, as they do for the ROD Remedy. Implementability risks associated with the two remedies are compared in Sections 5.9. Schedule considerations are reviewed in Section 6. Estimated costs for the Optimized Remedy are presented in Section 8.

5.8.7.1 Dewatered Sediments Transported to Upland Landfill

As illustrated in Figure 5-25A, this alternative for sediment disposal includes hydraulically dredging approximately 3.5 million cy of non-TSCA sediment in OU 3 and 4, and mechanically dredging and pressing an additional 30,000 cy from portions of OU 2 and 3 at the Shell Property and trucking the dewatered sediment to one of the three landfills identified in Table 4-9. Hydraulic dredging of 200,000 cy of sediment potentially subject to TSCA disposal requirements would be the other component of this alternative. The prospective TSCA material would be dredged as a separate activity, but would be dewatered in the same fashion and at the same location as the non-TSCA sediments. As discussed above, dredging activities would be sequenced and carefully monitored to isolate prospective TSCA materials during dewatering, staging and transport.

Sediments determined to be subject to TSCA disposal requirements will be transported to EQ Wayne Disposal in Belleville, Michigan; Peoria Disposal Company in Peoria, Illinois; or to another TSCA-permitted disposal location. Cost estimates for transport and disposal of Optimized Remedy dewatered TSCA sediment to both the EQ Wayne Disposal and the Peoria Disposal Company site are presented in Section 8.

Implementability evaluations presented in Section 4.2.3 identified 3 potential disposal sites for non-TSCA material that have also been considered for the Optimized Remedy:

- Brown County South – Wet Process Residue site (Figure 4-4)
- Brown County VandeHey – MSW site (Figure 4-5) or Wet Process site (Figure 4-6), but not both, and
- Onyx Hickory Meadows Landfill (Figure 4-7).

The implementability criteria included specific permitting and siting issues as listed on Table 4-8. Figure 4-8 shows the locations of the three potential landfill sites relative to the OU 2 to 5 project location.

Since the three potential sites each have adequate volume for disposal of Optimized Remedy dewatered sediments, other factors including socio-political acceptance, the ability to finish permitting and construction within the given timeframe, and cost will be considered prior to final selection of the disposal site(s). Key disposal site issues were discussed previously in Section 4.2.4, and are summarized below.

Brown County South Wet Process Residue Site. The wet process residue site at the Brown County South site currently has a completed Feasibility Determination from WDNR, but the Plan of Operation required for permitting of the facility has not been finalized. The wet process residue site would have potential capacity for approximately 3.7 million cy of material under the current Feasibility Determination, which is more than adequate for the Optimized Remedy. Given the age of the Feasibility Determination, it is possible that the County could revisit the siting process and local agreement for the wet process residue site. Future stakeholder interactions would be necessary to determine the course forward.

Brown County VandeHey Site. The MSW site has similar capacity to the Brown County site discussed above, and a separate proposed 3.7 million cy capacity wet process residue area. However, the VandeHey sites do not have a completed Feasibility Study. (The Feasibility Study was submitted to WDNR in 1994, but was subsequently withdrawn by the County.) In addition, since the siting process was put on hold by Brown County in 1994, residential development has continued to expand in the area surrounding the VandeHey site. These issues would have to be addressed in order for the VandeHey site to be a viable alternative.

Onyx Hickory Meadows Landfill Site. The Hickory Meadows Landfill site is located approximately 30 miles from OU 4 (RM 3.5), and is projected to have approximately 3.7 million cy of airspace remaining by the targeted start of dredging (2008). Onyx is contemplating a 7 million cy yard expansion of this facility but has yet to start the siting process. It is possible that such an expansion could be approved by 2010. The local agreement for the existing Onyx site allows for disposal of PCB contaminated sediment. The Onyx landfill is currently receiving dewatered sediment from OU 1 (see Section 1.7.1) and potentially will receive similar material from the Sheboygan River Superfund site (see Section 1.7.1).

Cost estimates for transport and disposal of Optimized Remedy dewatered sediment to either a wet process residue site (assumed for costing purposes to be the Brown County site) and the Onyx Hickory Meadows site are presented in Section 8.

In addition to the three potential disposal options discussed above, the RD will continue to evaluate other potential disposal sites for non-TSCA sediment that either have accepted PCB-containing sediment in the past or could do so in the future, including the Bayport Material Disposal Facility (see Section 4.3.4).

5.8.7.2 Sediment Slurry to Dewatering Landfill.

Transporting sediment via pipeline to a disposal facility within 20 miles of OU 3 and 4 that serves to both passively dewater the sediment and provides the final disposal location was an alternative that

the DEA identified as having potential and requiring further consideration when more sediment characterization work was completed. This alternative is illustrated on Figure 5-25(b).

As discussed in Section 4.2, neither the Brown County South wet process residue site (38 acres), nor the largest of the Brown County VandeHey sites (52 acres) can accommodate a dewatering landfill for disposal of the ROD Remedy sediment volume. However, with the Optimized Remedy, the sediment volume is reduced to a level that may be feasible for a dewatering landfill, and thus was evaluated further in this BODR. The volume requirement for a dewatering landfill is approximately 1.693 million cy after dewatering occurs to a value of 55 percent solids by weight. (A slightly larger disposal volume is required under the dewatering landfill option, compared with the mechanical dewatering option discussed above.) Assuming an average fill height of 30 feet, the disposal area requirement is roughly 35 acres.

Through design optimization it is possible that the Brown County South wet process residue site 38 acre footprint and/or the Brown County VandeHey site (52 acre municipal industrial landfill or 37 acre process residue site) could meet the disposal needs of the Optimized Remedy. The design capacity as a monofill for wet process residue at either site is approximately 3.7 million cy. A conceptual design of a dewatering landfill sufficient to accommodate the Optimized Remedy sediment volume is provided in Appendix A.

While pipeline transport to a dewatering landfill at the Brown County South wet process residue site or the VandeHey site is likely feasible, its costs are similar to the overall transport and disposal costs associated with mechanical dewatering and truck transport to the Onyx Hickory Meadows Landfill. Thus, for the purposes of this BODR, the Onyx landfill option was used as a basis for cost estimates of the Optimized Remedy presented in Section 8. Further stages of design development may include additional engineering evaluations and comparative evaluations of the dewatering landfill option.

5.9 Comparative Evaluation: ROD and Optimized Remedies

This section compares the Optimized Remedy (as described in Section 5) with the ROD Remedy, using the nine evaluation criteria set forth in the National Contingency Plan (NCP; 40 C.F.R. Part 300). As discussed in Appendix D, initial Workgroup efforts evaluated the potential extent of capping in the river consistent with the contingent remedy provisions of the ROD (see Section 5.1.2), and included a comparative evaluation of this initial option against each of the NCP criteria. A capping remedy was previously shown in the ROD to meet each of the individual NCP criteria (e.g., see Table 11-9 of the OU 3 to 5 ROD). The ROD indicated that if certain design, schedule, and cost criteria are met (see Section 5.1.2 above), the contingent remedy is considered a viable and protective alternative for OUs 3 and 4 and may be implemented (see ROD pp. 141 to 142). The shorter time frame and lower overall cost of the contingent remedy, relative to the ROD Remedy, was verified by the Workgroup as part of initial RD analyses, as summarized in Appendix D.

The results of the preliminary contingent remedy evaluations, along with the considerable new information collected during RD (see Section 5.1.1), were then used to develop and refine the Optimized Remedy design, combining elements of both the ROD Remedy and contingent capping remedy to further improve the overall remedy outcome. For example, as described in more detail in Sections 5.2 and 5.3, the Optimized Remedy often utilizes combinations of remedial technologies (e.g., dredging to a specified elevation, followed by placement of an engineered cap), where the ROD Remedy and contingent remedy applied only single technologies to specific areas (i.e., dredging or capping). This section presents a comparative analysis focusing on the relative performance of the Optimized Remedy and the ROD Remedy, referencing the results of the initial contingent remedy comparisons (presented in more detail in Appendix D) as appropriate to help inform the overall evaluation.

Table 5-2 presents a summary of differences in the dredging and disposal volumes between the ROD and Optimized Remedies. The estimated dredge volume under the ROD Remedy is approximately 7.6 million cy, and includes approximately 2.0 to 2.6 million cy of sediments containing estimated concentrations at or below 1 ppm PCBs that are located beyond the limits of the contaminated sediment neatline (see geostatistical analysis summaries presented in Table 2-12). The dredging volume is a direct result of the required design of the engineered dredge prism for the ROD Remedy, which targets removal with geostatistical confidence of all sediments in OUs 2 to 5 that exceed 1 ppm PCBs, and which accounts for constructability and anticipated overdredge allowances. This approach to dredge prism design is consistent with ROD requirements and with guidance provided by the Response Agencies and Oversight Team, as more specifically detailed in Sections 2.4 and 3.3.

Constructability considerations and overdredge allowances are also included in the target Optimized Remedy dredge volume (3.7 million cy; see Table 5-2), but in this case the dredge design has been optimized to:

- Reduce the volume of uncontaminated (less than 1 ppm PCBs) sediments removed from the project area, particularly within areas of OUs 3 and 4 characterized by relatively little PCB mass (see Section 2.3.2);
- Focus dredging towards those areas of the site where substantive mass removal can be more readily achieved (see Section 2.3.2);
- Dredge near-surface sediments to a specified depth as needed to provide for protective containment of deeply buried contaminated sediments, particularly within historical channel areas of OU 4 (see Section 2.3.3); and
- Integrate protective covers and caps into the overall Optimized Remedy design in a manner that provides a more uniform and constructable dredge surface, and recognizes the limitations of modern dredging equipment regarding dredge residuals (see Sections 5.2 and 5.3).

As discussed in Section 5.8, reduction of dredge volumes in the Optimized Remedy (relative to the ROD Remedy) allows for more judicious use of the limited capacity of regional landfill disposal facilities, and also reduces the dependence of the Optimized Remedy on pipeline easements, dewatering basin and landfill approvals, and landfill disposal agreements. These issues are discussed in more detail below.

5.9.1 Threshold Criteria

Overall Protection of Human Health and the Environment

The ROD Remedy and contingent capping remedy were determined by WDNR and USEPA to provide a similar level of human health and environmental protection. For example, as presented in Section 13 of the OU 3 to 5 ROD, an approximate 90 percent reduction of the OU 3 and OU 4 SWAC for PCBs is anticipated at the completion of sediment remedial actions under the ROD Remedy, relative to existing conditions. Model predictions referenced in the RODs suggest that over the long term, PCB concentrations in both water and fish tissue will steadily decline after implementation of the ROD Remedy, based on the combined effects of the remedy and subsequent long-term natural recovery processes. The implementation of the ROD Remedy is expected to achieve acceptable fish tissue PCB concentrations within approximately 20 to 60 years following completion of construction, depending on the specific receptor. As more specifically described in the Short-Term Effectiveness discussion below, the Optimized Remedy will achieve acceptable fish tissue PCB concentrations in a shorter time frame.

Because it combines remedial elements from both the ROD Remedy and contingent capping remedy, the Optimized Remedy will provide a similar level of human health and environmental protection, and will achieve acceptable fish tissue PCB concentrations within a shorter time frame. This comparable level of protection results from the mass removal and exposure reduction components of the Optimized Remedy. Mass removal is discussed in Section 5.9.2, below. With respect to exposure reduction, experience at a range of similar CERCLA dredging projects has shown that residual sediment contamination can be expected as a result of dredging (see Section 3.6.4). Based on the RD data and using typical residual percentages and sand cover mixing characteristics measured on other similar environmental dredging projects, the post-construction SWAC in OU 3 and OU 4 under the ROD Remedy is estimated at approximately 0.34 ppm and 0.41 ppm, respectively (Table 5-7), which are marginally above the SWACs targeted in the ROD (0.26 and 0.25, respectively). Using the same set of assumptions and calculations, the Optimized Remedy will likely attain a lower post-construction SWAC (0.28 ppm and 0.25 ppm, respectively), compared to the ROD Remedy (see also discussion of dredge residual management options in Section 5.6.1).

By integrating engineered caps and covers into the overall RD, the Optimized Remedy is expected to provide more effective and immediate control of post-dredge residuals, with the result that the post-

construction SWAC and restoration time frames will be lower under the Optimized Remedy than either the ROD Remedy or the contingent remedy. As discussed in more detail below, to the extent that the Optimized Remedy can be completed in less time than the ROD Remedy (see "Short-Term Effectiveness" below), and achieve a similar or lower SWAC at the completion of construction, the Optimized Remedy can be expected to reduce water and fish tissue concentrations and loadings to Green Bay sooner than the ROD Remedy.

As discussed in Sections 5.1 through 5.5, one of the goals of the Optimized Remedy is to design and apply caps only to those areas of OUs 2 to 5 where permanent stability and performance can be assured, based on the comprehensive RD sampling and analysis program and the outcome of detailed engineering evaluations. The Optimized Remedy has been designed to provide permanent chemical isolation and prevent future exposure to confined subsurface sediments. The technical design framework for cap design, presented in detail in Appendix D and summarized in Section 5.3 above, was developed based on agency guidance to ensure protectiveness (Palermo et al. 1998a), consistent with the ROD requirements for the contingent remedy. Furthermore, the long-term monitoring, maintenance, and contingency response requirements associated with the cap designs are included as integral parts of the Optimized Remedy design (and associated cost estimate) to ensure continued protectiveness. Monitoring and maintenance plans are discussed in Section 7.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

As discussed in Section 11.1.1 of the ROD, the ROD and Optimized Remedy must comply with substantive provisions of local, state, and federal laws and regulations including:

- Protection of surface water (NR 200, 220 to 297, and 322);
- Discharge to treatment plants or navigable waters (NR 105 and 106);
- Operation of wastewater treatment lagoons (NR 213);
- Air emissions related to the contingent vitrification technology (40 CFR 701 and HR 157 and 400 to 499);
- Prevention of spills and releases of PCB material (NR 140, 157, 200, and 220 to 297);
- Sediment disposal (NR 500 series and 40 CFR 761);
- Section 10 of the Rivers and Harbors Act (22 CFR 403); and
- Riparian rights (WI Statutes Chapter 30).

As discussed in WDNR and USEPA (2003), both the ROD Remedy and the contingent capping remedy are expected to equally comply with such ARARs, and the remedial designs for these remedies as outlined in this BODR have been developed to maximize compliance with ARARs. Again, because it combines remedial elements from both the ROD Remedy and contingent capping remedy, the Optimized Remedy will similarly comply with ARARs. For example, water treatment

ARARs have been considered in developing treated water discharge requirements for both the ROD and Optimized Remedies, as described in Sections 4.1.2 and 5.8.4, respectively. In addition, largely because dredging volumes equal or exceed capping volumes in both OU 3 and OU 4, the Optimized Remedy will not adversely affect the 100-year flood plain (see Figures 5-19 and 5-20 and Appendix D).

5.9.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Both the ROD and Optimized Remedies provide long-term effectiveness through a combination of dredging and containment of contaminated sediments. Both remedies also require some degree of institutional controls (i.e., fish consumption advisories until the remedial action objectives are met). The use of engineered capping on a broader scale for the Optimized Remedy may require evaluation during future phases of the RD of the appropriate level of institutional control for the selected remedy.

The dredge plan design developed for the ROD Remedy (see Section 3.3) removes approximately 92 percent of the near-surface mass (as defined in Section 5.1.4) within the target OU 2 to 5 remedial action area identified in the RODs (i.e., that reach of the river extending from OU 2 Deposit DD to the mouth of the river in OU 5; see Figure 2-1), and targets removal of approximately 90 percent of the total mass of PCBs in this area, excluding dredge residuals. When considering post-dredge residuals (which may range from 2 to 8 percent of the mass dredged), the ROD Remedy removes approximately 83 to 89 percent of the total mass of PCBs. All dredged sediments (approximately 7.6 million cy) will be disposed in off-site upland landfills. Much of the approximately 11 to 17 percent of PCB mass remaining within the river under the ROD Remedy (including residuals) will be retained predominantly in shoreline capping areas where dredging could negatively impact nearshore structures (see Figure 3-2), subject to further detailed analyses during the 30 and 60 Percent Design.

As discussed above and detailed in Sections 5.1 to 5.3, the dredge plan design developed for the Optimized Remedy includes many common elements of the ROD Remedy dredge plan, but focuses dredging towards those areas of the site where substantive mass removal can be more readily achieved, based on a core-by-core examination. Similar to the ROD Remedy, the Optimized Remedy is primarily a dredging action, removing approximately 92 percent of the near-surface mass (as defined in Section 5.1.4) within the target OU 2 to 5 remedial action areas (i.e., the region depicted in Figure 2-1). The Optimized Remedy removes approximately 62 to 66 percent of the total mass of PCBs in the project area, or approximately 74 percent of the mass of PCBs that would be removed under the ROD Remedy. All dredged sediments (approximately 3.7 million cy) will be disposed in

off-site upland landfills. The PCB mass remaining within the river under the Optimized Remedy is retained predominantly in the following areas:

- Discrete areas with deeper contaminated sediments that have been demonstrated to be stable (based on the sediment stability evaluations discussed in Section 5.1.4) and that do not contribute to site risks will be contained in place below engineered caps;
- Shoreline areas where dredging would negatively impact nearshore structures (see Figures 5-8 and 5-9) will be contained in place below engineered caps; and
- Existing sediments characterized by a relatively small amount of PCB mass (e.g., areas with low PCB concentrations, very thin deposits, or both) will be addressed through placement of either an engineered cap or 6-inch sand cover, depending on site conditions, where such containment systems can reliably achieve the risk-based performance objectives of the ROD.

To help depict where in the river the residual mass will be located, comparisons of PCB mass per unit area under existing conditions versus conditions following implementation of the Optimized Remedy are presented by depth interval (3-foot depth increments below the existing or post-remedy mudline) in Figures 5-26 and 5-27 for OU 2/3, and in Figures 5-28 to 5-31 for OU 4/5. These comparisons further highlight the extent of mass removal that will result from the Optimized Remedy, particularly within the shallower sediment depth intervals that have the greatest potential to influence site risks (see Section 5.1.4).

As required by the ROD and as detailed in Sections 5.3 and Appendix D, engineered caps have been designed to ensure the permanent containment of contaminated sediments. The cap designs used to develop the contingent remedy, and that were also applied to the Optimized Remedy, provide protective and reliable chemical isolation and ensure that erosion of the underlying sediment will not occur even in the face of major erosion events (e.g., floods, propeller wash, ice scour, and wind-waves.

To ensure the adequacy and reliability of controls for an in situ cap, similar to controls normally included with upland landfill confinement options as described in the ROD, a long-term monitoring, maintenance, and contingency response plan, including institutional controls and repair (as needed) of damaged capping areas, is included as part of the Optimized Remedy, as discussed above. A long-term cap monitoring plan will include both physical integrity monitoring (e.g., bathymetry surveys and sediment cores) as well as chemical analyses of surface sediments and cores collected from within the capping areas to verify the continued protectiveness of the caps over time (see Section 7). Specific institutional controls necessary to ensure long-term cap integrity are largely already in place (e.g., no anchor zones in the navigation channels and operation and maintenance agreements for the De Pere Dam), and will be assessed further during later stages of design.

Natural recovery modeling, as reported in the RI/FS, suggests that any residual sediment contamination that may remain on the post-dredge (or post-cap) surface will be expected to decline at

an accelerated rate following implementation of either remedy, as a result of overall sediment resuspension controls and ongoing sedimentation processes. Monitoring of surface sediment recovery within dredging areas could be implemented to verify such natural recovery expectations. Detailed monitoring plans will be necessary for both the ROD Remedy and the Optimized Remedy, and will be developed during subsequent stages of RD.

Reduction of Toxicity, Mobility, or Volume through Treatment

For reasons set forth in the Lower Fox River RI/FS and ROD, both the ROD Remedy and contingent remedy utilize permanent solutions to the maximum extent practicable. This is true for the Optimized Remedy as well, since it addressed the same site conditions and is based on similar design criteria.

Both the ROD Remedy and Optimized Remedy would remove large sediment volumes and accompanying PCB mass from OUs 2 to 5, and contain such materials in upland landfills to eliminate mobility. Both remedies also use in-place containment to eliminate mobility of PCBs that are not removed. However, neither the ROD Remedy nor the Optimized Remedy satisfies the statutory preference for treatment (e.g., see Section 11.2.2 of the OU 3 to 5 ROD). Given the large volumes of material involved the RODs determined that treatment was unlikely to be cost-effective. This was verified during development of this BODR.

As discussed in Section 4.2.1 above, vitrification of OU 2 to 5 sediment was tested on a pilot-scale as part of USEPA's SITE demonstration. Based on a comparative evaluation (see Appendix B and Section 8), large-quantity vitrification was confirmed as not cost-effective.

Short-Term Effectiveness

Short-term effectiveness relates to the length of time needed to implement an alternative and the risks that the alternative poses during implementation. As more specifically detailed in Section 6, the total estimated implementation time frames for the ROD Remedy and Optimized Remedy are as follows:

- **ROD Remedy – about 15 years**, with the possibility of a significantly longer duration (e.g., up to 24 years) based on uncertainties regarding difficulties that may be encountered with concurrent operation of 2 hydraulic cutterhead dredges and the time required to obtain or modify the necessary pipeline easement, dewatering basin and landfill approvals, and landfill disposal agreement. The ROD Remedy schedule developed for this BODR, as presented in Section 6.2, is anticipated to be approximately 1.5 times longer than the implementation time frame envisioned in the OU 3 to 5 ROD.
- **Optimized Remedy – about 9 years**, with fewer uncertainties that could affect project duration (see Section 6.3 and Implementability discussion below).

Based on the detailed project schedule presented in Section 6, construction of the Optimized Remedy can be completed at least 6 years faster than the ROD Remedy, and presents fewer contingencies such as pipeline easements, dewatering basin and landfill approvals, landfill disposal agreements, and concurrent dredge operations that could extend the duration of remedy implementation. Thus, the Optimized Remedy will achieve protectiveness more rapidly than the ROD Remedy.

Similar staging areas are envisioned, and weather-related impacts are expected to be similar for both remedies. The shorter overall duration of the Optimized Remedy construction, resulting from a lower dredge volume, will reduce the number of seasonal shut-downs relative to the ROD Remedy. Because of the shorter duration, for similar types of construction activities, the potential impacts on the environment and human health (e.g., to workers and the community) during remedial construction will be less for the Optimized Remedy than for the ROD Remedy. A commensurate reduction in potential impacts associated with noise, air emissions, dust, and interference with river traffic during construction is also expected under the Optimized Remedy.

The Optimized Remedy and the ROD Remedy use similar dredging equipment, , but the Optimized Remedy includes higher production rates resulting from a more constructable dredge prism and does not require a mixing tank to manage dredge slurry and feed it into a pipeline. The Optimized Remedy also uses hydraulic dredging equipment (versus mechanical dredging equipment) for sediments potentially subject to TSCA disposal requirements. Short-term water quality and residuals impacts associated with dredging activities, as discussed in Section 3.6.3, will be similar between remedies for activities performed within a given construction season, but will extend for a longer duration under the ROD Remedy. Thus, greater short-term water quality impacts are expected under the ROD Remedy.

Resuspension of contaminated sediment during dredging is anticipated, along with associated water quality and dredge residual impacts as discussed in Sections 3.6.3 and 3.6.4. Based on available monitoring data from other similar projects (USEPA 2005b), measurable resuspension typically occurs during initial placement of capping material, and progressively decreases and dissipates with each subsequent placement as the operator gains experience. These results also suggest that resuspension during cap placement may be minimized by placing cap materials in several lifts, with the use of minimal disturbance (i.e., low energy) methods for the initial lift followed by more aggressive techniques for subsequent lifts. These construction techniques have been included in the Optimized Remedy (see Appendix D), and are expected to result in fewer short-term water quality and dredge residual impacts than the ROD Remedy.

Implementability

As discussed in the OU 3 to 5 ROD, implementability relates to the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as the availability of services and materials, administrative feasibility, and coordination with government entities and other stakeholders are considered in the implementability evaluation. While the ROD identified that dredging, transport, disposal, and capping technologies were all potentially feasible in OUs 2 to 5 from a technical and administrative standpoint (i.e., all such technologies have been implemented successfully on many other remedial projects), several key issues were nevertheless identified that were evaluated further in this BODR.

The following differences in implementability between the ROD and Optimized Remedies have been identified (not necessarily in order of potential importance):

- The relatively large non-TSCA disposal requirements associated with the ROD Remedy (approximately 5.6 million dewatered tons; see Table 4-1) will require a minimum of two separate NR 500 landfill disposal facilities. Only three potential disposal sites have been identified to date (see Section 4.2), and two of these are associated with Brown County's proposed solid waste facilities. Given the age of the Feasibility Determination for one of the two Brown County sites, and the lack of a Feasibility Study for the other, the status of these sites for prospective disposal of OU 2 to 5 sediments is uncertain. Depending on the specific site(s) targeted for disposal, and on local agreements as may be negotiated for this project, these disposal site uncertainties may extend the ROD Remedy construction schedule by 1 to 5 years, and with an uncertain outcome. The possibility of a 1 to 5 year delay is generally included in the upper end of the schedule range discussed above, but any additional delay or infeasibility resulting from an inability to use either of the Brown County facilities would be above and beyond the schedule range.

  As discussed in Section 5.6.7, compared with the ROD Remedy, the Optimized Remedy includes a smaller non-TSCA sediment disposal requirement (approximately 1.8 million dewatered tons), and only a single NR 500 landfill will be required. This landfill could be either of the Brown County landfills or the currently permitted Onyx Hickory Meadows facility, or a combination of these facilities.

- The pipeline easement negotiated by WDNR for possible use under the ROD Remedy is subject to termination under certain conditions, creating uncertainty over the 15 to 24-year duration of the construction project. In addition, opposition to portions of the prospective pipeline has been expressed by Brown County residents and government representatives. These transportation uncertainties could extend the ROD Remedy construction schedule by 1 to 3 years or more, and with an uncertain outcome. If the pipeline ultimately cannot be built or must be prematurely removed, sediment will have to be trucked from the river to multiple landfills, increasing ROD Remedy costs well above the cost estimate presented in this BODR. In addition, there will be numerous road, driveway or ditch crossings associated with the pipeline that will have to be buried or encased. These special sites (estimated at approximately 50) will require additional focus and design since they will experience higher wear than the straight sections of pipeline and will not be readily accessible for rolling to distribute the wear. The possibility of a 1 to 3 year delay is generally included in the upper end of the schedule range discussed above.

The Optimized Remedy does not rely on pipeline transport and therefore does not face these pipeline-related uncertainties.

- The ROD Remedy will utilize passive dewatering processes to achieve solids contents to facilitate disposal in an NR 500 landfill. As discussed in Section 4.2, because of the dredge slurry volumes involved in the ROD Remedy, very few locations for the requisite NR 213 dewatering basin at an existing or proposed solid waste management facility have been identified. Moreover, recent experience in OU 1 with a passive dewatering process (geotubes) revealed uncertainty in the ability of the passive process to sufficiently dewater the dredged sediments to produce a workable material at the landfill. Therefore, sediment dewatering under the ROD Remedy will likely require the use of an amendment (e.g. quicklime) to achieve the required solids content for landfill disposal. Other factors such as varying dredge material physical characteristics and weather can impact a passive dewatering system. As discussed in Section 4.1, preliminary evaluations indicate that the addition of amendments will be necessary following passive dewatering in the NR 213 settling basin. The costs of such have not been included in cost estimate presented in Section 8. A need for amendments based on an inability to sufficiently dewater the sediments passively would increase the ROD Remedy costs (and potentially the schedule) above the estimates presented in this report.

  Under the Optimized Remedy, sediments will be mechanically dewatered to obtain sufficiently high solids contents for landfill disposal, using a process similar to that used for the SMU 56/57 demonstration project. However, varying dredge material physical characteristics can impact a mechanical dewatering system, requiring careful monitoring and adjustment of the dewatering process for the specific sediments being addressed. An inability to sufficiently dewater the sediments mechanically would increase the Optimized Remedy project costs and schedule above the estimates presented in this report. Thus, in comparison to the ROD Remedy, the Optimized Remedy has some of the same uncertainty due to changes in sediment quality; however, redundant dewatering equipment is planned to reduce operational uncertainty.

- Concurrent operation of 2 hydraulic cutterhead dredges discharging into a common receiving tank with a single 18 mile pipeline for transport has not been implemented in any other environmental project on the scale of the ROD Remedy. Technical difficulties and reduced efficiencies during operation of this system could extend the ROD Remedy construction schedule by 1 to 9 years (part of the schedule uncertainty discussed above) and increase the ROD remedy costs above the cost estimate presented in this report.

  As discussed above, varying dredge material physical characteristics can also impact the efficiency of the Optimized Remedy, requiring careful monitoring and adjustment of processes for the specific sediments being addressed. Similar to the ROD Remedy, such factors could increase the Optimized Remedy schedule beyond the time frame presented in this report. Thus, the Optimized Remedy faces some of the same process efficiency implementation challenges that the ROD Remedy would face. However, the Optimized Remedy does not require concurrent operation of two dredges and therefore is not subject to that particular uncertainty regarding implementability.

- The ROD Remedy dredge prism developed for this BODR to limit disposal volume is a relatively complex plan (see Figures 3-1 and 3-2), that may be difficult to implement. Contractor efficiency impacts that could occur during dredging may extend the ROD Remedy construction schedule by 1 to 2 years (part of the schedule uncertainty discussed above). In addition, it is possible that the ROD Remedy dredge prism may need to be simplified to improve constructability, though such a simplification would increase the amount of clean,

non-neatline sediment removed from the river, thereby increasing the construction schedule and cost of the ROD Remedy above the schedule and cost estimate presented in this report.

The Optimized Remedy dredge plan is more implementable (from a dredge operation perspective) than that developed for the ROD Remedy, because of a more uniform and constructable dredge surface. However, the Optimized Remedy involves somewhat more complex combinations of sediment remediation technologies in certain reaches of the river than the ROD Remedy. This complexity can be managed through careful planning and sequencing.

Cost

Detailed cost estimates (present worth basis) were developed for both the ROD Remedy and Optimized Remedy. As detailed in Section 8, the estimated total present worth costs of the ROD Remedy and Optimized Remedy are as follows:

- ROD Remedy – $580 million; and
- Optimized Remedy – $390 million.

5.9.3 Modifying Criteria

Agency Acceptance

For either the ROD Remedy or Optimized Remedy to be implemented, approval from EPA and WDNR will be necessary through an ESD or ROD Amendment process, and through approval of subsequent detailed remedial design documents. The ROD Remedy was previously selected by EPA and WDNR, though certain changes to the remedy as described in this BODR are contingent upon approval from EPA and WDNR through an ESD or ROD Amendment. Active agency participation in the Optimized Remedy workgroup is occurring to ensure early resolution of agency concerns.

Community Acceptance

The level of community acceptance of the Optimized Remedy will be gauged through public comments received as part of the ESD or ROD Amendment process.

5.9.4 Comparative Evaluation Summary

A detailed summary of the specific elements of the ROD Remedy and Optimized Remedy, highlighting key similarities and differences, is presented in Table 5-9. The comparative NCP evaluation of the two remedies, as discussed above, is summarized in Table 5-10. Key elements of the comparative evaluation include:

- Like the ROD Remedy, the Optimized Remedy provides overall protection of human health and the environment and complies with ARARs. Though the two remedies involve different mixes of technologies, the Optimized Remedy and the ROD Remedy provide comparable levels of long-term effectiveness, permanence, and reduction of toxicity, mobility, and volume.
- The Optimized Remedy can be initiated and completed more rapidly than the ROD Remedy, providing more short-term effectiveness than the ROD Remedy. The Optimized Remedy will also achieve acceptable fish tissue PCB concentrations in a shorter time frame than the ROD Remedy.
- The Optimized Remedy is more implementable than the ROD Remedy. For instance, the Optimized Remedy incorporates a more uniform and constructable dredge surface than the ROD Remedy. In addition, the Optimized Remedy relies on sediment dewatering and transport methods that are proven on similar scale projects and that minimize the need for additional infrastructure. The Optimized Remedy also uses existing permitted disposal capacity. For these and other reasons, the Optimized Remedy presents fewer dredging, transportation, and disposal uncertainties than the ROD Remedy.
- The Optimized Remedy can be implemented at lower cost than the ROD Remedy.

Table 5-9. Summary of Lower Fox River OU 2-5 Remedial Design Scenarios

Component	Units	ROD Remedy	Optimized Remedy
1. Prospective TSCA Dredging and Disposal			
a. Estimated Dredge Volume (OU 4)	*in situ* cy	210,000	200,000
b. Dredging Method	-	Mechanical	Hydraulic Cutterhead
c. Dewatering Method	-	Amendment	Mechanical Press
d. Assumed Handling Facility	-	GP/Shell Property	GP/Shell Property
e. Assumed Off-Site Transport Method	-	Truck	Truck
f. Assumed Disposal Facility	-	EQ Wayne Disposal (MI)	EQ Wayne Disposal (MI)
g. Alternate Disposal Facility	-	Peoria Disposal Company (IL)	Peoria Disposal Company (IL)
2. Non-TSCA Dredging and Disposal			
a. Estimated Dredge Volume (with overdredge)			
OU 2	*in situ* cy	81,000	24,000
OU 3	*in situ* cy	716,000	204,000
OU 4	*in situ* cy	6,552,000	3,258,000
Total [(a)]	*in situ* cy	7,349,000	3,486,000
b. Dredging Method	-	2 Hydraulic Cutterheads	1 Hydraulic Cutterhead
c. Desanding Method	-	Desanding/Flotation/Attrition Scrubbing	Desanding/Flotation/Attrition Scrubbing
d. Estimated Separated Sand Volume	cy	530,000	225,000
e. Assumed Desanding/Storage Facility	-	GP/Shell Property	GP/Shell Property (w/ shoreline fill)
f. Off-Site Sediment Transport Method	-	Mixing Tank / Pipeline	Truck
g. Estimated Disposal Wt. (dewatered)	*tons*	5,604,000 [(b)]	1,815,000
h. Assumed Dewatering Method	-	NR 213 Basin at Brown County South	Mechanical Press
i. Assumed Disposal Facility	-	Brown County South AND Onyx	Onyx Hickory Meadows
k. Alternate Transport Method	-	N/A	Pipeline (w/out mixing tank)
l. Alternate Dewatering Method	-	Dewatering Landfill	Dewatering Landfill
m. Alternate Disposal Facility	-	VandeHey	Brown County South or VandeHey
n. Average Production Rate	*in situ* cy/day	4,790	3,190
o. Approximate Dredging Duration	years	11 to 15	8
3. Beneficial Use of Separated Sand			
a. Estimated Beneficial Use Volume	cy	530,000	225,000
b. GP/Shell Staging Facility Fill	cy	20,000	150,000
c. Post-Remedy Staging Area Use	-	Site redevelopment & wharf use	Site redevelopment & wharf use
d. Non-Remedial Beneficial Use Volume	cy	510,000	75,000
e. Non-Remedial Beneficial Use Options	-	See Section 4.3	See Section 4.3
4. Sediment Caps and Covers			
a. Target Sand Volume	cy	640,000 (primarily residual cover)	890,000
b. Target Gravel Volume	cy	65,000 (shoreline caps)	390,000
c. Target Quarry Spalls Volume	cy	0	20,000
d. Transport and Placement Method	-	Barge & Rehandling Bucket	Barge & Rehandling Bucket
5. Overall Performance Metrics			
a. Total Project Duration	years	15 +	9
b. OU 3 / OU 4 SWAC	ppm PCBs	< 0.26 / < 0.25	< 0.26 / < 0.25
c. Near-Surface PCB Mass Removed	%	92%	92%
d. Total PCB Mass Remediated	%	99%	99%
e. Total PCB Mass Removed	%	83 to 89% (depending on residuals)	62 to 66% (depending on residuals) 75% of ROD Remedy removal
f. Total Cost	Present worth	$580 million [(c)]	$390 million

(a) Excludes sediment along shorelines and near structures where dredging may not be technically feasible.
(b) Disposal weight includes additional weight of dewatering amendment, as discussed in Section 4.1.
(c) Total cost does not include increase associated with likely use of dewatering amendment to achieve the 50 percent solids necessary for final disposal.

Table 5-10. CERCLA Evaluation Criteria Comparison

CERCLA Criteria	ROD Remedy	Optimized Remedy
1. Overall Protection of Human Health	YES – Acceptable risks achieved 20 to 60 years after completion of remedial actions, depending on the receptor. Long-term monitoring plan (and maintenance and contingency response plan for shoreline capping) to ensure protectiveness.	YES - Acceptable risks achieved 20 to 60 years after completion of remedial actions, depending on the receptor. Long-term monitoring, maintenance, and contingency response plan to ensure protectiveness.
2. Compliance with ARARs	YES - Expected to meet ARARs	YES – Expected to meet same ARARs as ROD Remedy plus additional ARARs regarding capping.
3. Long-Term Effectiveness and Permanence	YES - Requires some degree of institutional controls (i.e., fish consumption advisories until the remedial action objectives are met). ROD Remedy removes approximately 92 percent of near-surface PCB mass in OU 2 to 5 project area sediments. Nearshore areas that cannot be dredged without adverse impacts to shoreline structures will be permanently contained below engineered caps.	YES - Requires some degree of institutional controls (i.e., fish consumption advisories until the remedial action objectives are met). Optimized Remedy removes approximately 92 percent of near-surface PCB mass in OU 2 to 5 project area sediments. Overall, the Optimized Remedy removes approximately 74 percent of the PCB mass targeted for removal under the ROD Remedy. Remaining sediment with PCB concentrations greater than 1 ppm will be permanently contained.
4. Reduction of Toxicity, Mobility, or Volume through Treatment	YES - Overall mobility reduction through upland containment. Possible treatment of approximately 210,000 cy of sediments potentially subject to TSCA disposal requirements, pending verification of performance, implementability, and cost-effectiveness.	YES – Overall mobility reduction through a combination of upland and cap containment. Possible treatment of approximately 200,000 cy of sediments potentially subject to TSCA disposal requirements, pending verification of performance, implementability, and cost-effectiveness.
5. Short-Term Effectiveness	YES - Project duration estimated to range from 15 to 24 years, depending on difficulties encountered with concurrent operation of 2 dredges, and the time required to obtain pipeline easements and landfill disposal agreements (see Section 6.2).	YES - Project duration estimated to be approximately 9 years (see Section 6.3). Shorter period of construction water quality impacts and other construction-related impacts.
6. Implementability	YES - Services, materials, and equipment are locally available (except hydraulic dredges). However, landfill capacity is limited (at least 2 separate NR 500 landfills will be required for disposal). Necessary pipeline easements are also uncertain. Operational difficulties of two dredges to a common pipeline are also uncertain. Capping included in ROD Remedy near shoreline structures and utilities. Likely use of dewatering amendment would reduce implementability due to increased complexity.	YES - Services, materials, and equipment are locally available (except hydraulic dredges). Smaller sediment disposal volume allows more transport and landfill options (only one of several existing and/or potential future NR 500 landfills required). Capping included in Optimized Remedy near shoreline structures and utilities, and in other areas of the site to optimize the remedy.
7. Cost (in millions of dollars)	$580 million (see Section 8.2)	$390 million (see Section 8.3)
8. Agency Acceptance	ROD Remedy was previously selected by EPA and WDNR, though certain changes to the remedy as described in this BODR are contingent upon approval from EPA and WDNR through an ESD or ROD Amendment.	Contingent upon approval from EPA and WDNR through an ESD or ROD Amendment.
9. Community Acceptance	Prior public opposition to pipeline easements and landfill disposal in certain locations.	Public comments will be solicited through ESD or ROD Amendment process.

6. CONSTRUCTION SCHEDULE AND SEQUENCING

This section describes the general operations sequencing of remedial actions and the likely durations of the ROD Remedy and Optimized Remedy. For both alternatives, coordination with USACE navigational dredging within the channel as well as beneficial use of separated sand will occur throughout the duration of the project. These activities will occur concurrently with the dredging and are not anticipated to impact the schedule significantly.

The preliminary construction schedules for both remedies were developed assuming an average in-water construction window of approximately 180 days between May 1 and October 31. Variations in the seasonal opening and closing date of this construction window are expected from year to year. Assuming the contractor works 6 days per week during this construction window, an average of approximately 154 working days per year are available to implement the remedial action. During other times of the year, cold weather will prevent water-based work. All construction schedules presented in this BODR do not include activities occurring prior to Agency approval of initiation any construction-related tasks.

6.1 Operations Sequencing

Remedial actions for both the ROD and Optimized Remedies will employ the same general sequence. This sequence of operations must take into consideration the thickness of dredge cuts, extent of capping, duration of work, type of equipment, and methods for verifying that the remedial actions achieved the required objectives. While the general sequence of operations is fairly simple, the timing of events is highly dependent upon the factors listed above, as described below. The general sequence of operations would include:

- Dredge and/or cap a specified area to the required elevation and grades per the design. Each specified area may be referred to as a Sediment Management Unit (SMU). The reason for delineating each OU into discrete SMUs is to break up the large area represented by each OU into smaller sections that can be dredged/capped and surveyed (e.g., by a third-party surveyor) to verify completion of remedial action within a reasonable timeframe. In this way, the potential for deposition or erosion causing discrepancies between the contractor's daily progress surveys and the post-construction verification survey can be limited. These SMUs need to be small enough to avoid waiting too long between start of construction and the completion of construction in the area such that significant scour or erosion could occur. However, the areas need to be large enough so as not to require excessive third party survey events. The post-construction third-party survey is typically used for measurement and payment purposes and verification of successful completion of remedial actions. As a worst case example, if the post-construction survey was conducted only after completing all of the remedial actions in OU 4, several construction seasons would pass before a survey was conducted and the post-construction survey would likely not reflect the condition of large portions of site after they were initially dredged or capped. At a minimum, a post-

construction survey would be completed near the end of each construction season. Contractor progress surveys will be conducted on a more frequent basis to control the work.

- Both non-TSCA sediment and materials potentially subject to TSCA disposal requirements would be delineated into discrete SMUs. Because a relatively small volume of sediments potentially subject to TSCA disposal requirements are present in OUs 2 to 5 (all of these materials are in OU 4; see Figure 24), each discrete area of such sediments would likely be designated as an individual SMU and dredged and surveyed independently.
- The SMU may be dredged in one single pass of the dredge, or multiple passes of the dredge. The number of passes is typically dependent upon the thickness of the dredge cut, the location of dredging, and the type of equipment used. The thickness of each dredge cut lift is dependent upon the type and size of equipment that the contractor selects to use for the site. For a thin cut (e.g., 2 feet or less), both a mechanical or hydraulic dredge would be capable of removing this entire lift with one pass of the dredge equipment. For thick cuts, the contractor may use two or more passes to achieve the required elevations and grades. The contractor may also choose to leave a thin cut to be removed as a final cleanup pass to try to minimize dredged material residuals. However, this method is not typical since leaving a thin cut of material significantly reduces the project effective production rate.
- During the dredging operations, the contractor would perform daily bathymetric progress surveys to verify accuracy of their work. These daily progress surveys would be used to help adjust the contractor's operations to comply with the project specifications.
- Once a specified area or SMU is completed, as reported by the contractor, a third-party independent bathymetric survey is typically conducted to confirm that the area has been adequately completed. If high spots remain after dredging within the SMU, the contractor would be required to remove those high spots and the area would be checked again by bathymetric survey. Similarly, if low spots remain after capping, the contractor would be required to place additional material to reach the design grades and the area would be checked again by bathymetric survey (Details of the construction performance monitoring plan will be developed as part of the 60 Percent Design, but Section 7 presents preliminary concepts for this monitoring.
- Once the area has been accepted as complete, post-construction sampling would be conducted. Section 7 presents a preliminary plan of post-construction monitoring and contingency actions; more detailed plans would be prepared as part of the 60 Percent Design Submittal. The timing of the post-construction monitoring has not been decided, but could occur immediately after completing each SMU, at the end of a construction season, or at the end of dredging an entire OU.

6.2 ROD Remedy Schedule

Under a reasonable "best-case" scenario (see Section 5.9 above), the estimated total duration to complete remedial actions under the ROD Remedy is approximately 15 years including approximately 3 years for the dewatering of the last NR 213 cell and transfer to the NR 500 disposal facility occurring after the completion of in-water dredging. This assumes two dredges will be efficiently working within OU 4/OU 5 at the same time. If during construction only one dredge is determined to be feasible the duration of this project would extend an additional, 8 to 9 years. This assumes that site preparation, including construction of the slurry pipeline and NR 213 dewatering

facility (and/or NR 500 landfill), will be performed during the first year, prior to any in-water dredging of non-TSCA sediment. Some sediment potentially subject to TSCA disposal requirements that are present near the staging/offloading facility will be dredged during Year 1 as part of the deepening of the access berth at the offloading facility. With the exception of dredging of OU 4 surficial sediments potentially subject to TSCA disposal requirements, which will occur during Year 2 of the remedial action (see below), dredging will occur in a general upstream to downstream sequence throughout the remedial action, with one 12-inch hydraulic cutterhead dredge initially working in OU 2 and OU 3. Since only one dredge will be used in OUs 2 and 3, a "make-up" water pump will be required during dredging operations in OUs 2 and 3 to provide the necessary flows to maintain proper operation of the pipeline to the NR 213 dewatering facility. The pipeline is designed to handle flow from the two hydraulic dredges that would operate in OU 4. Once remedial actions in the upstream OUs are completed (estimated to be completed in early Year 4), a second 12-inch hydraulic cutterhead dredge will be mobilized to OU 4, and both dredges will work concurrently for the remainder of the project, obviating the need for the make-up water pump. Sequencing remedial actions in this manner will minimize the potential for recontamination (e.g., from dredge residuals) resulting from remedy implementation.

Beginning in Year 2, surficial sediments in upper OU 4A that are potentially subject to TSCA disposal requirements, including relatively highly contaminated sediments in the area depicted in Figure 2-20, will be removed using mechanical dredging equipment, amended with a dewatering agent at the staging facility, and transported by truck to an approved TSCA landfill facility (likely Wayne Disposal or Peoria Disposal). Subsurface deposits potentially subject to TSCA disposal requirements, which are present in several locations throughout OU 4 (Figure 2-24), will be sequenced to provide removal of these materials shortly after the overlying non-TSCA sediments are dredged. Figure 6-1 presents a Gantt chart illustrating the preliminary remedial action schedule for the ROD Remedy. The top part of Figure 6-1 illustrates the schedule assuming two hydraulic dredges are used in OU 4/OU 5 area; the bottom part of the figure shows the schedule if only one dredge is determined to be feasible in this area. Additional implementation risk factors, which could also extend the ROD Remedy schedule, are discussed in Section 5.9. As more specifically described in Sections 3 and 4 of this BODR, the ROD Remedy scheduling will include the following:

- Landfill Preparation. Landfill construction will be phased over a number of years. The first cell of the landfill as well as two NR 213 basins must be ready to accept non-TSCA sediment prior to dredging of non-TSCA sediments. The landfill will require a minimum of four cells. Each of the three subsequent cells will be constructed every other year. The NR 213 basin will also likely be built over a phased plan. The first two basins will be constructed initially, then another in Year 2, and the final in Year 3. See Section 4 for more detail on landfill preparation.
- Pipeline Installation. The pipeline from the staging facility desanding operation to the NR 213 basin will require roughly 4 months constructing. The pipeline construction will be

sequenced such that it is operational at roughly the same time as the first cell and the two NR 213 basins.

- Staging Facility Preparation. The Shell Property or suitable equivalent will be developed as a staging area. Preparation will include grading the site and installing utilities as well as construction of shoreside facilities for adding dewatering amendment to sediments potentially subject to TSCA disposal requirements, berthing access for floating equipment, and stockpile areas for beneficial re-use sand and capping material. Construction of the desanding operation will also occur at the staging facility during preparation. Access to the site via water will require installation of a sheet pile bulkhead (see Section 3.7). Roughly 4 months will be required to prepare the staging facility.
- Mobilization of Dredging Equipment. Two hydraulic dredges and a mechanical dredge will eventually be mobilized to the site. Note that the second hydraulic dredge will not be mobilized until Year 4 just prior to OU 4/OU 5 dredging. Mobilization of the hydraulic dredge and support equipment will coincide with pipeline installation. Mechanical dredge and support equipment will coincide with the preparation of the staging facility. At the end of each construction season, time will be required to demobilize and winterize equipment. Set up time will also be required at the beginning of each construction season to mobilize equipment. The schedule assumes that the time for both operations will occur outside of the 180 day in-water construction period.
- Removal of Sediments Potentially Subject to TSCA Disposal Requirements. Once the staging facility is prepared, dredging of the surface sediments that may be subject to TSCA disposal requirements can commence. Under the ROD Remedy, a mechanical dredge will be used to remove sediments potentially requiring TSCA disposal. The sediment will be offloaded at the staging facility, dewatered as necessary, and hauled to the TSCA landfill. Subsequent dredging of subsurface sediment will occur as the overlying non-TSCA sediment is removed. Mechanical dredging of the sediment potentially subject to TSCA disposal requirements is anticipated to occur at a rate of approximately 1,200 cy/day. See Section 3 for supporting discussion on production rates. Dredging of the surface sediments in the prospective TSCA areas will require approximately 13 weeks; the cumulative time for removing the subsurface sediments is 17 weeks. However, given the spatial distribution of sediment potentially subject to TSCA disposal requirements sediments, and that some such sediments are buried beneath non-TSCA sediments, the removal of sediments potentially requiring TSCA disposal requirements will be performed in stages over approximately 8 to 10 years.
- Non-TSCA Sediment Removal—OU 2/OU 3. Sediments within OU 2 and OU 3 will be dredged hydraulically with a single dredge (note: a ‘make-up” water pump will be required to provide the necessary flow rate to maintain pipeline operation). Hydraulic dredging of the sediment is anticipated to occur at a rate of approximately 2,400 cy/day (see Section 3). OU 2 sediment will require approximately 6 weeks of dredging; OU 3 sediment will require roughly 50 weeks of dredging. Sediment removal will generally occur in an upstream-to-downstream sequence to minimize the potential for recontamination.
- Non-TSCA Sediment Removal—OU 4. Two hydraulic dredges will be used to remove non-TSCA sediment in OU 4. Hydraulic dredging of the sediment is anticipated to occur at an average rate of approximately 2,400 cy/day per dredge (see Section 3). Both dredges will remove the OU 4 non-TSCA sediment over a cumulative 230-week dredging period. If only one dredge is feasible in the OU 4/OU 5 area than the dredging time duration extends to 460 days.

- Sediment Desanding. Bench-scale testing of OU 3 and 4 sediments performed during the RD evaluation demonstrated that relatively uncontaminated sand (less than the 1 ppm RAL) can be practicably separated from the more contaminated silt and clay materials (see Section 4). Initial removal of coarse material will also facilitate pipeline transport of sediments to the disposal site, as generally described in the ROD. Accordingly, desanding of dredged sediments will occur at the staging facility prior to pipeline transport. Separated sands will be beneficially used as staging area fill materials and in off-site applications as such uses are identified. The duration for this activity will coincide with the hydraulic dredging operations.
- Sediment Dewatering and Disposal. Desanded sediments will be transported by pipeline to a dedicated engineered landfill, consistent with Wisconsin Administrative Code NR 500 regulations. Prior to disposal, sediments will be dewatered in an NR 213 basin or equivalent dewatering landfill facility. This activity will initially coincide with the hydraulic dredging operations, but will extend approximately 3 years or beyond the completion of dredging for final dewatering and landfill closure.
- In situ Capping of Shoreline Areas. In situ capping of sediments exceeding the 1 ppm RAL may be performed along shoreline areas where dredging could not be completed without adversely impacting the stability of the existing slopes. Capping would occur at a rate of approximately 675 cy/day per crew in OU 3 and 1,620 cy/day per crew in OU 4/OU5. Duration of approximately 12 weeks will be required for the entire shoreline cap placement. These activities will occur near the completion of respective dredging activities.
- Post-Dredge Residual Management. Dredge residual management will likely be required to meet the overall SWAC goals specified in the RODs, and may include placement of an approximate 6-inch layer of sand on the dredge surface, monitored natural recovery, or redredging to attempt to remove the settled materials. Residual covers are discussed in more detail in Section 5. Residual covers will be placed using mechanical equipment, at a rate of approximately 900 cy/hr in OU 2 and OU 3, and at a rate of approximately 2,200 cy/hr in OU 4/OU 5. The total duration of residual cover placement will be approximately 18 weeks for OU 2/OU 3 and approximately 28 weeks for OU 4/OU 5.
- Demobilization and Site Restoration. Demobilization and site restoration will involve removing equipment from the staging and work areas and restoring the site to its original condition before construction of the staging area commenced. The wharf constructed at the staging facility is assumed to remain in-place.

6.3 Optimized Remedy Schedule

Section 5 describes in detail the Optimized Remedy, which builds on the ROD Remedy and integrates capping and other alternative remedial measures as appropriate. The estimated total duration of the Optimized ROD Remedy is approximately 9 years. This duration includes the 18 months required for design, procurement, and installation of sediment dewatering and water treatment equipment prior to initiating in-water work. It also includes 12 weeks for project demobilization. The Optimized Remedy will utilize one 12-inch hydraulic dredge for a large majority of sediment removal; a mechanical operation will be used to remove OU 2 sediments and a portion of OU 3 sediments near shore. Dredged sediment will be dewatered at the Shell Property or equivalent staging facility. Dewatered sediment will then be hauled by truck to the landfill. Similar to the ROD Remedy, surficial sediments in OU 4 that are potentially subject to TSCA disposal requirements will be

removed during Year 2, while such subsurface deposits will be removed after the overlying non-TSCA sediments are dredged. In addition, some sediment potentially subject to TSCA disposal requirements that are present near the offloading facility will be dredged during Year 2 as part of the deepening of the access berth at the offloading facility. Capping will be completed concurrently with dredging. Capping will be completed with one capping crew working concurrently and sequenced to minimize the potential for recontamination of cap surfaces from adjacent dredging.

Figure 6-2 presents a Gantt chart illustrating the schedule for the Optimized ROD Remedy alternative. As more specifically described in Section 5 of this BODR, the Optimized ROD Remedy scheduling will include the following:

- Staging Facility Preparation. The Shell Property or equivalent will be developed as a staging area. Preparation will include grading the site and installing utilities as well as constructing waterfront structures for materials shipping. A dewatering facility will need to be constructed on the property to handle the hydraulically dredged material. Separate stockpiles will also be established for the dewatered dredge material, sand material removed, and capping materials. To facilitate water access to the site, the Optimized Remedy includes dredging of the area in front of the Shell Property to accommodate barges and cargo ships delivering aggregate with 15 to 19.5 feet of draft. Staging area construction is discussed in Section 5.8.5. Following verification sampling to confirm suitability, surficial soils from the adjacent Shell Property uplands will be used as initial fill materials and placed behind the sheet pile wall. Separated sand from the dredge material will be used for the remaining fill. Roughly 18 months will be required to design, procure, and install the dewatering and water treatment equipment and prepare the Shell Property for the project.
- Mobilization of Dredging Equipment. One hydraulic dredge and supporting equipment will be mobilized to the site. Cap placement equipment will also be mobilized. Mobilization of dredging equipment is anticipated to require 6 weeks. At the end of each construction season a period of approximately 3 to 4 weeks will be required to demobilize and winterize equipment. A similar amount of time will be required at the beginning of each construction season to re-mobilize equipment and set up operations. The schedule assumes that the time for both operations will occur outside of the 180 day construction period.
- Removal of Sediments Potential Subject to TSCA Disposal Requirements. A hydraulic dredge will be used to remove sediments potentially subject to TSCA disposal requirements. The sediment will be pumped to the Shell Property, dewatered and hauled as necessary to the TSCA landfill. Subsequent dredging of subsurface sediments potentially subject to TSCA disposal requirements will occur as the overlying non-TSCA sediment is removed. Hydraulic dredging of the sediments potentially subject to TSCA disposal requirements is anticipated to occur at a rate of approximately 3,200 cy/day.
- Non-TSCA Sediment Removal—OU 2/OU 3. Sediments within OU 2 and a small portion of the OU 3 sediments will be dredged using mechanical equipment. This dredging is anticipated to occur at a rate of approximately 1,800 cy/day. The anticipated total mechanical dredge time for both OU 2 and OU 3 is approximately 3 to 4 weeks. Sediment removal will generally occur in an upstream-to-downstream sequence to minimize the potential for recontamination.

- Non-TSCA Sediment Removal—OU 3. One hydraulic dredge will be used to remove the non-TSCA sediment in OU 3 that was not removed with mechanical equipment. Hydraulic dredging of the sediment is anticipated to occur at a rate of approximately 3,200 cy/day. The dredge will remove the OU 3 non-TSCA sediment in approximately 12 weeks.
- Non-TSCA Sediment Removal—OU 4/OU 5. One hydraulic dredge will be used to remove non-TSCA sediment in OU 4 generally working from upstream to downstream. Hydraulic dredging of the sediment is anticipated to occur at a rate of approximately 3,200 cy/day. The dredge will remove the OUs 4 and 5 non-TSCA sediment in approximately 162 weeks.
- Sediment Desanding, Mechanical Dewatering, and Truck Transport. Bench-scale treatability testing of OU 3 and 4 sediments performed during the RD evaluation has demonstrated that relatively uncontaminated sand (less than the 1 ppm RAL) can be practicably separated from the more contaminated silt and clay materials. Accordingly, desanding of dredged sediments will occur at the Shell Property processing facility prior to dewatering. Separated sands will be beneficially used for a portion of the staging area fill as described above, and in other on-site and off-site applications as such opportunities are identified. The remaining sediments will be dewatered with mechanical equipment and hauled by truck to the landfill. Alternatively, sediments could potentially be transported via pipeline to a dewatering landfill (see Section 5.8.7.2). In either event, the duration for these activities will occur during the hydraulic dredging operations.
- In situ Capping of Shoreline Areas. In situ capping of sediments exceeding the 1 ppm RAL may be performed along shoreline areas where dredging could not be completed without adversely impacting the stability of the existing slopes. Capping would occur at a rate of approximately 675 cy/day per crew in OU 3 and 1,620 cy/day per crew in OU 4/OU5. Duration of approximately 6 weeks will be required for the entire shoreline cap placement. These activities will occur near the completion of respective dredging activities.
- Post-Dredge Residual Management. Dredge residual management will likely be required to meet the overall SWAC goals specified in the RODs, and may include MNR, placement of a nominal 6-inch layer of sand on the dredge surface, or redredging (if deemed appropriate) to attempt to remove the settled materials. Residual covers will be applied using mechanical equipment. Residual covers will be applied at a rate of 900 cy/hr in OUs 2 and 3 and at a rate of 2,160 cy/hr in OUs 4 and 5. The total duration of residual cover placement will be approximately 6 weeks for OUs 2 and 3 and 13 weeks for OUs 4 and 5.
- Cap Placement. A greater amount of capping is included in the Optimized Remedy, relative to the ROD Remedy. The capping will be completed utilizing one crew of mechanical equipment. Caps will consist of a lower sand section with either gravel or quarry spall armoring (depending on the location as described in Section 5). Placement of all cap materials will occur at a rate of 900 cy/hr in OUs 2 and 3 and at a rate of 2,160 cy/hr in OUs 4 and 5. Caps in OU 3, and OU 4/OU 5 will require 42 weeks, and 47 weeks, respectively to construct.
- Demobilization and Site Restoration. Demobilization and site restoration will involve removing equipment from the staging and work areas and restoring the site to its original condition before construction of the staging area commenced. However, if the property owner agrees and the Response Agencies approve, infrastructure or property improvements may be left in-place (i.e. the bulkhead constructed at the staging facility is assumed to remain in-place).

7. MONITORING AND MAINTENANCE MEASURES

Detailed construction (short-term) and post-construction (long-term) monitoring and maintenance plans will be prepared as part of the Intermediate (60 Percent) Design documents, which are scheduled to be submitted to the Response Agencies in fall 2006, depending on the progress of earlier RD activities. Construction monitoring activities, including water quality monitoring and sediment confirmation sampling, will be specified in the Construction Quality Assurance Plan (CQAP). Long-term monitoring activities, including cap performance monitoring and long-term monitoring of water and biota in the Lower Fox River and Green Bay, will be specified in the Operations, Maintenance, and Monitoring Plan (OMMP). The basic components and framework of these plans are described in this section.

7.1 Construction Quality Assurance Plan (CQAP)

Water column monitoring during construction activities, including dredging, contingent capping, and dredged material disposal activities will be described in the CQAP (see Section 7.2, below). Air monitoring activities will also be described (see Section 7.3, below). These monitoring activities will be specified to ensure construction best management practices (BMPs) are being properly implemented and to prevent construction activities from unduly impacting the river or bay. One of the objectives of the CQAP is to achieve the Remedial Action Objective—"Minimize the downstream movement of PCBs during implementation of the remedy"—as specified in the ROD.

Also in the CQAP, a sediment confirmation sampling program will be designed to confirm the attainment of remedial action levels (RALs) in sediments (see Section 7.4, below). If RALs are not met, a range of response actions may be appropriate.

7.1.1 Operation, Maintenance, and Monitoring Plan (OMMP)

Certain elements of the remedial action will require long-term maintenance and monitoring, and such activities will be covered under the OMMP. This will include, for example, maintenance and monitoring of capped areas to ensure the cap remains physically stable (i.e., does not erode) and chemically protective (see Section 7.5, below). Also included in the OMMP is a long-term monitoring plan (LTMP) which describes the program for monitoring water and aquatic biota in the years following the remedial action, to verify that the remedial action was effective at reducing risk to human health and the environment (see Section 7.6, below). Data collected under this plan will be used to help determine the magnitude and extent of reductions in PCB concentrations over time in response to the remedial action.

7.2 Construction Water Quality Monitoring

Elutriate tests were conducted to evaluate the potential for water quality effects during dredging and disposal activities (see Sections 3.2.3 and 4.1.2, respectively). The elutriate test results indicate TSS and turbidity can be used as reliable indicators for other chemicals of concern. Moreover, if water quality meets the TSS limit currently being applied in OU 1- no greater than 80 mg/L increase above ambient concentrations - water quality effects from other constituents would not be expected. Because TSS samples must be collected and submitted to an analytical laboratory, monitoring for a TSS surrogate (e.g. turbidity) in real time in the field has been proven in OU 1 to be a more effective way to provide meaningful feedback to the contractor regarding the effectiveness of BMPs at controlling water quality impacts. A site-specific correlation between TSS and turbidity will be established during the pre-construction survey (see Section 7.2.3).

7.2.1 Monitoring Locations

During construction activities, upstream and downstream turbidity monitoring will be conducted using an in situ nephelometer. The upstream station will be located approximately 500 feet upstream of the dredge. The downstream station will generally be maintained between 250 feet and 500 feet downstream of the dredge, and in no case greater than 500 feet downstream, the length of the mixing zone boundary.

The in situ nephelometers will need to be periodically repositioned as the dredge moves. At each station, turbidity will be monitored at three depths—near-surface (within 3 feet of river surface), intermediate (midpoint of the water column), and near-bottom (within 3 feet of the river bed).

7.2.2 Pre-Construction Monitoring

Prior to construction, water quality monitoring will be performed to establish ambient water quality conditions, and to develop a quantitative correlation between turbidity levels and TSS concentrations in the Lower Fox River. Pre-construction monitoring will be conducted over a range of conditions, including a range of river flows, seiches, and runoff events, to the extent possible. However, ambient conditions will continue to be monitored during construction at the upstream monitoring station, because the pre-construction monitoring program cannot capture the full range of conditions that may be realized during the multi-year construction project.

A key objective of the pre-construction monitoring survey is to develop an empirical correlation between turbidity, which can be measured in real time, and TSS, which must be analyzed at a contract laboratory. Based on this correlation, a turbidity criterion will be developed which is equivalent to the TSS limit. The proposed turbidity criterion, and underlying statistical basis, will be presented in the Pre-construction Monitoring Report.

7.2.3 Water Quality Monitoring Schedule

Turbidity will be monitored according to one of two schedules:

- Intensive Monitoring (continuously for one week)
- Routine Monitoring (continuously for one construction shift per week)

Intensive monitoring will be initiated at the following times:

- Startup of any construction activity (i.e. dredging, disposal, capping, cover placement)
- Major modification to construction procedures (i.e., change of dredging method)
- Upon exceedance of the turbidity criterion at the mixing zone boundary

Intensive monitoring will be conducted during the first week following the startup or major modification of a construction activity. If the turbidity criterion has not been exceeded within this period, monitoring may continue at the routine frequency.

7.2.4 Response Actions

If an exceedance of the turbidity criterion occurs at the mixing zone boundary, the Contractor will be required to immediately notify WDNR and USEPA, and modify operations (e.g., slowing dredging or placement rate), implement additional structural controls, or take other measures as necessary to correct the problem. Based on past dredging experience during demonstration projects and full-scale OU 1 remedial actions in the Lower Fox River, dredging sediments at the bedrock or native clay contact, or in areas of excessive debris may generate unusually high turbidity. Short-term turbidity excursions may be unavoidable under these field conditions, and will be considered in the evaluation of water quality data.

Dredging activities will cease at the first indication of distressed or dying fish, or the generation of a significant oil sheen in the vicinity of dredging operations. The source of the fish impacts or sheen will be identified and controlled before operations are resumed

7.3 Air and Noise Monitoring

7.3.1 Air Monitoring

Each of the upland disposal remedial alternatives involves some form of dredging, dewatering, water treatment, handling and transport of the material from the river vicinity to a landfill for disposal. Based on past experience at similar sites, the planned site activities are not expected to cause air emission impacts; however, given the variety of activities planned for OUs 2 to 5, it may be necessary to conduct some confirmatory monitoring for PCBs in the immediate vicinity of the project. This could consist of continuous air monitoring at the beginning of the project to ascertain the potential

impact throughout the gamut of operations. If ongoing monitoring demonstrates that PCB concentrations are not detected or are present at minimal levels, the monitoring program could be reduced to once per week, conducted periodically at prescribed times throughout the project, or discontinued.

If air monitoring is performed, it is anticipated it would include the use the same type of high volume samplers that have recently been used in OU 1. This equipment consisted of a Tisch Environmental TE-PUF or its equivalent, loaded with a combination quartz filter and Polyurethane Foam (PUF) cartridge, following EPA TO-4A protocols. Air would be drawn through the sampler at about 8 cubic feet per minute (226 Liters per minute). Sampling periods will be at least 72 hours to ensure sufficient sample and volume to permit detection of PCBs at low concentrations. All samples would be analyzed pursuant to the analytical procedures in the EPA TO-4A protocol.

7.3.1.1 Air Monitoring during Demonstration Projects

Based on past experience with air quality measurements for particulates and PCBs during two PCB sediment dredging demonstration projects (Deposit "N" and SMU 56/57), it was concluded there would be little impact on human health or the environment. With respect to volatilization, a significant amount of air monitoring for PCBs was performed during the 1999 SMU 56/57 demonstration project, which used similar remediation technologies as proposed for OUs 2-5. During this demonstration project, some of the highest PCBs concentrations in the Lower Fox River (up to 400 ppm) were remediated. The December 2002 *Fox River and Green Bay ROD for OU1 and OU2* concluded that "air monitoring during the …dredging project demonstrated that even under 'worst case' conditions (i.e., when sediments are excavated and exposed to the air), volatilization of PCB's do not pose significant risk to humans or wildlife."

7.3.1.2 Air Monitoring in OU 1

Pursuant to the requirements of the ROD for OUs 1 and 2, an ambient air monitoring program has been developed and implemented for remedial actions in OU 1. While remedial actions in OU 1 to date have utilized a dewatering technology (geotubes) not proposed for OUs 2 to 5, the largest potential source of particulate and PCB emissions was theorized to be related to the transfer of sediment material to trucks. The air monitoring program has consisted of four stations strategically located around the perimeter of the dewatering, wastewater treatment, and load-out upland facilities. Air sampling was performed continuously before remediation began to establish a baseline, and has been performed throughout the remedial activities. All of the results have been below the limit of detection for PCBs, which was 0.5 micrograms per sample. Although air volumes varied slightly from sample to sample, this translates generally into a calculated PCB concentration that is less than 0.0004 ug/m^3 for each sampling station and sampling event.

7.3.2 Noise Monitoring

As indicated in Section 3.6.5, noise monitoring is rarely conducted on environmental dredging projects and operations in OU 1 have not indicated substantive concerns regarding unacceptable noise levels. While it is not anticipated that dredging or capping operations will contribute significantly to unacceptable noise levels, contractors will need to be cognizant of community noise ordinances for certain areas. If necessary, a contractor may need to demonstrate how it will meet the substantive requirements of the applicable ordinance. This may require certain limited noise monitoring at the perimeter of the operations if they impinge on residential areas.

7.4 Post-Dredge Sediment Confirmation Sampling

Post-dredge confirmation sampling will be performed following completion of dredging. The purpose of this post-dredge confirmation sampling will be to verify predicted dredging residuals concentrations and to identify areas where contaminated sediment deposits may remain below the dredge cut (i.e., undredged inventory). Results from all environmental dredging projects completed to date reveal that residuals are an inevitable consequence of the dredging process. In this BODR, residual concentrations have been predicted based on an assumed 5 percent mass release of the material in the dredge prism, based on the average residual reported from other comparable environmental dredging projects (see Section 3.6.4). The confirmation sampling program will inform the need for and scope of post-dredge management actions. As discussed above, details of the post-dredge confirmation sampling plan will be developed as part of the 60 Percent Design submittal.

Post-dredge confirmation sampling results will be compared to the 1 ppm RAL. If the monitoring data indicate that the post-dredge surface does not meet the RAL, the area will be evaluated in conjunction with the SWAC in that OU. The need for additional response actions to address post-dredge residuals or undredged inventory is generally discussed in this BODR and will be developed in more detail during development of the 30 and 60 Percent Design submittals. Additional post-dredge response actions could include:

- No action;
- Additional sampling to verify the accuracy of the initial sampling data (this may include “short cores” if undredged inventory is suspected);
- Placement of a sand cover;
- Placement of an engineered, armored cap; and
- Additional cleanup pass dredging (if appropriate).

A process will be devised during later stages of design to provide a decision tree basis for determining the appropriate residuals management option in an adaptive management context. Surficial concentration and mass of PCBs will be considered as part of the decision process. Appropriate post-dredge response actions will also discern between residuals and undredged inventory.

7.4.1 Confirmation Sampling Plan

Confirmation sampling will be performed within the following areas:

- **Dredge areas:** This includes the footprint of the dredge prism specified on the construction plans.
- **Dredge boundary areas**: This includes certain areas along the perimeter of the dredge footprint, especially where elevated residuals are expected to occur. Focused sediment sampling will be performed early during the remedial action to verify the horizontal extent of residuals.
- **Dredge residual cover areas**: This includes initial sampling to confirm proper placement of 6-inch sand covers as needed to achieve the SWAC, and adaptive management of cover placement techniques if necessary.
- **Cover only areas**: This includes areas where the Optimized Remedy includes placement of a 6-inch sand cover without prior dredging.

The remainder of this Section presents the preliminary plan for confirmation sampling within these areas. Section 7.5 presents the plan for monitoring of engineered cap areas.

7.4.1.1 Dredge Footprint and Boundary Areas

Following completion of dredging within a given dredge management area, surface sediment (top 10 cm) confirmation samples will be collected within and immediately adjacent to the dredged areas. It is anticipated that confirmation samples will be collected in batches subsequent to the completion of the dredging activities within specific segments of the river. Sample batches will be determined based on the construction sequencing achieved by the contractor(s).

For the purpose of costing in this BODR (Section 8) it was estimated that the level of effort for confirmation sampling will be approximately 20 percent of the surface sampling locations collected during the 2004-2005 RD investigation, with some consideration of additional sampling required for adaptive management. The confirmation sampling plan will likely include more dense coverage in areas of higher predicted residuals concentrations and/or greater uncertainty due to geostatistical interpolation (see Section 2.3), and less dense coverage in areas of lower predicted residuals concentrations or lower uncertainty. In areas where surface sediment concentrations are significantly higher than predicted residuals concentrations, “short cores” (e.g., manually deployed 12- to 24-inch piston cores) will be obtained to determine whether undredged inventory may be present below the residuals layer.

During the initial round(s) of post-dredge sampling, the confirmation grid will also include the margins of the dredged areas, specifically, the fringe area between a significance level of 0.5 and 0.3, as defined in Section 2.3. This area roughly corresponds with the dredge boundary areas discussed above, where resuspended sediment may have been transported during dredging. An adaptive

management plan will be developed as part of the 60 Percent Design Submittal which will be used during construction to adjust the confirmation sampling plan within this fringe area based on the results of the initial round(s) of sampling.

Compositing Scheme. Confirmation samples will be prepared as 5-point composites for chemical analysis. Typically, the composite sediment samples will be made up of 5 individual samples representing the center and four corners of each post-dredge confirmation area (like five dots on a die). Alternatively, the five individual samples may be aligned in a row to characterize post-dredge sediment quality in or along linear features such as the unmaintained navigation channel in OU 4A. An equal aliquot from each of the five individual samples will be mixed together to form the composite sample, and the remaining material from the individual samples will be separately archived for possible future analysis.

Estimated Sample Numbers. In the ROD Remedy, dredging affects 1,180 acres of OUs 2 to 5. In the Optimized Remedy, dredging affects approximately 555 acres of OUs 2 to 5. In either remedy, the fringe area between significance levels of 0.5 and 0.3 is estimated at 280 acres (see Table 2-12). The estimated number, location, and density of composite sediment samples will be developed as part of the 60 Percent Design submittal.

7.4.1.2 Dredge Residual Cover and Cover Only Areas

Confirmatory monitoring of cover areas (both dredge residual cover and cover only areas) will be performed during the course of construction to verify remedial design predictions regarding the degree of mixing that occurs between the cover material and the underlying sediments. Monitoring will be based on a combination of physical observations and focused chemical analysis

Monitoring will include collection and visual/photographic observation of short-cores (e.g., manually deployed 12- to 24-inch-long piston cores) collected immediately after placement at representative cover locations. The cores will be examined (and documented with photos) to characterize the extent of sand mixing into the underlying sediments. Such monitoring would verify the effectiveness of the placement approach and would allow adjustments to be made to the construction process or post-construction SWAC calculation procedure, if necessary. In addition, the results of the initial round of cover sampling will be used to verify the mixing anticipated during placement as described in Section 5.4.1. Follow-on confirmatory monitoring during the course of construction would be performed on a periodic basis on a subset of cover locations to continue to document the protectiveness of covers placed during construction.

7.4.2 Evaluation of Confirmation Sampling Results

The determination of whether RAL and SWAC targets have been achieved in OUs 2 to 5 will be based on measurements available at the time that remedial construction is completed. Post-dredge monitoring would be performed to characterize undredged inventory and dredge residual concentrations, thicknesses, and densities, and post-cover placement monitoring would be performed to verify compliance with cover specifications (e.g., 6-inch target thickness). Targeted post-cover placement monitoring would also be performed to verify remedial design predictions of the degree of mixing that occurs between the cover and underlying sediments, using a combination of physical observations and focused chemical sampling. Details of sample collection and interpretation associated with these post-construction monitoring activities would be provided as part of the 60 Percent Design submittal.

At the end of each construction season and also at the completion of remedial actions in each OU, the OU-wide SWAC would be calculated. Based on a review of this information, annual adjustments to construction operations could be made as necessary to ensure that the ROD-specified SWAC targets are achieved. Post-construction SWAC calculations would be performed within OUs 3 & 4 using the following guidelines:

- No Action Areas – use existing surface sediment (0 to 10 cm) concentrations as measured during the 2004 and 2005 remedial design sampling;
- Engineered Cap and Dredge-and-Cap Areas – assume post-construction surface sediments in these areas are zero;
- Dredging-Only Areas – use post-dredge surface sediment concentrations measured in these areas (note: all dredging-only areas with residual surface sediment concentrations exceeding the 1 ppm RAL would be subject to additional response actions [e.g., sand cover], and will be addressed differently in the SWAC calculation, as outlined below);
- Dredge-and-Cover Areas – calculate post-cover surface sediment concentrations based on the verified degree of mixing between measured post-dredge (i.e., pre-cover) surface sediment concentrations, and the cover (assumed to have zero concentration); and
- Cover-Only Areas – calculate post-cover surface sediment concentrations based on the verified degree of mixing between surface sediment concentrations measured in these areas during 2004 and 2005, and the placed cover (assumed to have zero concentration).

Note that the specific areas where a cover will be applied cannot be determined in advance, but will be determined based on confirmation sampling results as required to meet the SWAC.

7.5 Cap Performance Monitoring

Cap performance monitoring includes short-term performance issues that will be monitored during construction (e.g., ensuring that the specified thickness and extent is achieved), and long-term performance issues that will be monitored in the post-construction period (e.g., ensuring that the cap

remains physically and chemically stable over its design life). The details of the cap construction and monitoring program are being developed as part of the 60 Percent Design submittal. The following program is typical of what has been done at other similar sites and has been included for costing purposes. Monitoring activities to control short-term and long-term performance issues will be described in more detail in the CQAP and OMMP, respectively, to be developed as part of the 60 Percent Design.

7.5.1 Cap Monitoring during Construction (CQAP)

The main performance issues that will be monitored during the construction of sediment caps include the following:

- Achieving Specified Thickness and Extent. Capping material must be satisfactorily placed over the required areas and to the required thicknesses.
- Verification of Import Material Quality. The chemical and physical characteristics of the capping material must be verified as appropriate for their intended use.
- Release of Suspended Sediment. In situ contaminated sediment may become resuspended during capping operations and redeposited on the river bed.

7.5.1.1 Achieving Specified Cap Thickness and Extent

Contractor Quality Control hydrographic and/or topographic surveys will be performed before and after capping materials are placed to confirm that sufficient cap thicknesses were placed in the target cap areas. In addition, a limited number of cores will be collected after cap construction to verify cap thickness and correlate with bathymetric surveys. During the 60 Percent Design, a detailed decision tree will be developed to address triggers for additional cap placement based on construction performance. The following are general components that may be included in that decision tree for evaluation of discrete sediment management areas (SMA), generally sized based on approximately 2 weeks worth of work:

- If the majority (specific percentage to be determined during RD) of the capping area is at or above design grade ("target thickness"), no maintenance action will be necessary.
- If less than the majority of the area is at or above grade, cores will be collected and the post-cap bathymetry in that SMA reviewed to determine if the SMA has more than the required minimum cap thickness and would be expected to self-level through hydrodynamic forces such that the majority of the area would be at or above grade. The need for cap maintenance would be determined on a case-by-case basis.

7.5.1.2 Verification of Cap Material Quality

Possible material that may be used to construct sediment caps may include the following:

- Imported material from approved source(s)
- Clean dredged material from approved source(s)

The physical and chemical properties of any material used for capping must first be characterized. At a minimum, representative samples of proposed cap material will be analyzed for:

- Grain Size
- Total Organic Carbon
- Metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn)
- PCBs (Aroclors)

7.5.1.3 Control of Suspended Sediment

The Contractor will monitor water quality during capping activities, consistent with the procedures described in Section 7.1. The Contractor will be required to place caps in a manner that will minimize the release of suspended sediment. If water quality criteria are not being met at the mixing zone boundary of the capping activity (same as that for dredging as described in Section 7.2.1), additional operational or structural BMPs may need to be implemented (e.g., limiting the fall distance of cap material through the water column, using tremie pipes, diffusers, etc.).

7.5.2 Long-Term Cap Performance Monitoring and Maintenance (OMMP)

The objectives of the cap monitoring program are to detect and evaluate any changes in the physical or chemical properties of the cap that would compromise its integrity (i.e., reduce its expected performance period). The physical integrity of the cap is monitored to ensure the cap thickness does not diminish by erosion. The chemical integrity of the cap is monitored to ensure that chemicals of concern in the underlying sediments do not migrate through the cap and into the river. A flow chart outlining the decision framework that will be used to interpret the results of long-term cap performance monitoring is shown on Figure 7-1. Given that completion of capping is anticipated to take several years, monitoring will occur independently within the three general site areas: OU 3, OU 4A, and OU 4B. The “Year 0” trigger for post-construction cap monitoring in a given area will occur when cap construction is completed within that area.

7.5.2.1 Physical Integrity of Sediment Caps

Subaqueous Caps. An initial post-construction hydrographic survey of the capped areas will be performed immediately following completion of the remedial action. As discussed above, a limited number of sediment cores will also be collected through the completed cap to correlate to the

hydrographic survey. This initial post-construction survey and correlated cores will verify that cap placement specifications have been met, and establish the baseline (Year 0) cap condition for the subsequent assessment of long-term changes in cap thickness.

Post-construction hydrographic surveys of the capped area will be completed and a limited number of cores will be collected during Years 1, 4, and 9 following completion of the remedial action, such that the results could be incorporated into the 5 and 10-year CERCLA reviews. In addition, hydrographic surveys will be performed as soon as possible following any flood event with a recurrence interval of 50 years or more. Hydrographic surveys may also be performed following major river construction events (e.g. new bridge construction) or significant changes in waterway use (e.g. channel reauthorization, etc.). The details of such monitoring triggers will be developed during the 60 Percent Design.

To the extent possible, survey data will be collected along the same transects from year to year to ensure comparable data are collected. Changes in bathymetry over time will be evaluated to identify areas of potentially significant erosion, deposition, or consolidation. Initially, erosion will be estimated based on elevation loss in hydrographic surveys or from regularly-scheduled cores collected in cap areas. In capped areas with significant elevation loss (to be defined in greater detail as part of the 60 Percent Design submittal), follow-on sediment cores will be collected to determine whether the elevation loss has occurred as a result of erosion or settlement based on visual assessment of cap thickness in the core sample, and in consideration of core compaction. If the required thickness of cap material is present in the core sample, it will be determined that settlement has occurred rather than erosion.

Bank Caps. In addition to hydrographic surveys, bank surveys will be performed during low-water conditions to monitor caps placed on river banks and side-slope areas. The bank surveys would include:

- Field reconnaissance for evidence of erosional features (i.e., presence of gullies, escarpments, slumps, etc.).
- Monitoring elevation changes using stakes embedded in the cap.
- Follow-up land surveying as necessary.

If the low-water field surveys show significant cap erosion has occurred on the banks, follow-up hydrographic and/or diver surveys may be conducted in the adjacent areas of the river to determine whether the erosion extends into deeper water.

Response Actions. Similar to the approach outlined in Section 7.5.1 for performance monitoring immediately following placement of the caps, a decision tree will be developed during the 60 Percent

Design to evaluate physical integrity monitoring results. This decision tree may include the following general evaluation criteria:

- If the majority (specific percentage to be determined during RD) of the capping area is at or above design grade ("target thickness"), no maintenance action will be necessary.
- If less than the majority of the area is at or above grade, cores will be collected and the post-cap bathymetry in that sediment management area (SMA) reviewed to determine if the SMA has more than the required minimum cap thickness and would be expected to self-level through hydrodynamic forces such that the majority of the area would be at or above grade. The need for cap maintenance would be determined on a case-by-case basis.

If cap erosion is confirmed by collected cores, possible response actions can include but are not limited to:

- No action if the chemical analytical results indicate the remaining cap thickness is sufficient to prevent “breakthrough” of contaminants
- Repair area of erosion (re-establish cap thickness)
- Armor area of erosion
- Enact managerial or institutional controls, such as changes to vessel operations, to help control any further cap erosion.

Consistent with CERCLA requirements, the Response Agencies and Respondents will evaluate cap performance and the need for and scope of continued cap monitoring as part of the five-year review process.

7.5.2.2 Chemical Integrity of Sediment Caps

The chemical integrity of capped areas will be assessed using a combination of surface sediment samples and subsurface sediment cores, as described below.

Surface Sediment Samples. Surface sediment samples will be collected in all capped areas. Consistent with the procedures used to sample dredged areas (see Section 7.4.1), composite grab samples will be collected and analyzed. Composite confirmation samples will typically be comprised of five individual grab samples, although fewer individual grabs may suffice in smaller capped areas. An aliquot of each individual grab sample will be separately archived for possible future analysis, in case it is determined that finer spatial resolution is needed. Surface sediment sampling in the capped area will be completed during Years 1, 4, and 9 following completion of the remedial action.

In the Optimized Remedy, an estimated 400 acres will be remediated by either capping or a combination of dredging and capping. These acres would be included in long-term cap integrity monitoring. The specific number and location of cap monitoring samples, including surface samples and subsurface cores, will be developed as part of the 60 Percent Design submittal.

The purpose of the surface sediment samples is to monitor for chemical breakthrough of the cap. If any composite sample results are above 1 ppm PCBs, the individual grab samples which comprise those composite samples will be analyzed, as shown on Figure 7-1. If the individual sample results confirm the composite sample result, a sediment core will be collected in that area, as described below.

Sediment Cores. Sediment cores extending through the cap and into underlying sediments (approx. four-foot cores) will routinely be collected in representative capped areas with above-average river currents and chemical gradients as part of the long-term cap monitoring as shown on Figure 7-1. It is estimated that ten cores would be routinely collected and assigned to this purpose, and would serve as sentinels for cap performance.

In addition to the routinely collected cores within the cap areas, sediment cores will be collected in specific locations where surface grab samples indicate that PCB concentrations exceed 1 ppm in the surface layer, as described above and shown on Figure 7-1.

The cores will be subsectioned and analyzed for PCBs and TOC. The core profiles will be analyzed for evidence of chemical migration through the cap, and evidence of "breakthrough" in which the chemical has migrated through the full thickness of the cap and into the overlying river. If breakthrough has occurred, or is predicted to occur before the design life of the cap is reached, additional response actions will be evaluated.

Response Actions. Each sediment core collected for evaluation of chemical breakthrough will be evaluated on a case-by-case basis. If chemical profiles in sediment cores indicate cap breakthrough may have occurred, possible response options can include but are not limited to:

- Increasing the thickness of the cap to ensure cap integrity.
- Increasing the frequency and intensity of cap monitoring.

For the purposes of this BODR an estimate was made of the potential maintenance that may be required to caps placed as part of either the ROD Remedy (shoreline capping only) or the Optimized Remedy (shoreline caps and engineered caps). The maintenance records of previously completed capping projects were reviewed to determine an appropriate level of maintenance. Maintenance records from the caps that have been in place for more than 15 years (e.g., a number of estuarine and river caps constructed in the Pacific Northwest; e.g., Sumeri 1996) indicate that maintenance of approximately 5 percent of the total cap area may be needed after 2 years of monitoring. After appropriate modifications to the armor stone size, further cap maintenance has not been required at any of these capping sites (up to 20 years after construction) following initial maintenance. Therefore maintenance of the Lower Fox River cap was assumed to be necessary over 5 percent of the total cap area (excluding 6-inch covers under the ROD Remedy). In order to develop conservative cost

estimates (see Section 8) localized, maintenance was assumed necessary at 1, 4, 9, and 30 years following construction and at 20-year intervals thereafter, based on the possible occurrence of large but infrequent storms

7.6 Long-Term Monitoring

Water and biological tissue are the media of interest for long-term monitoring of risk reduction to humans and wildlife as a result of the sediment remedial action. Both media will be sampled and analyzed at a number of stations from Lake Winnebago to Green Bay. The water monitoring plan generally consists of systematic monthly sampling of 10 stations over the course of an entire year. The fish tissue monitoring plan includes sampling of 5 different species at 8 different stations, in replicates of 5 to 15 samples for each species at each station. Both water and fish tissue monitoring programs are scheduled to include a baseline (pre-construction) event, a Year 0 (construction completion) event, and to be implemented on a five-year cycle thereafter during the post-construction period.

The final details of the Long-Term Monitoring program are being developed through a collaborative Work Group process. The draft plan submitted to the Intergovernmental Parties was used to develop the costs used for the BODR.

7.6.1 LTMP Objectives

The overall objective of the Long-Term Monitoring Plan (LTMP) is to evaluate the rate and magnitude of risk reduction that occurs in response to the sediment remedial action. Specific objectives of the Long-Term Monitoring Plan include the following:

7.6.1.1 Establish Pre-Remediation Conditions

Baseline (pre-remediation) water and fish tissue quality conditions in the Lower Fox River and Green Bay will be characterized to provide a point of comparison for long-term (post-remediation) monitoring data. The combined baseline and long-term monitoring data will provide the Response Agencies with sufficient information to determine whether the implemented remedy meets risk reduction success criteria.

7.6.1.2 Monitor Progress toward Achieving RAOs

Long-term monitoring data will be collected to evaluate progress toward achieving the RAOs of reduced risk to humans and wildlife, as presented in the RODs (WDNR/EPA 2002, 2003). More specifically, these RAOs include the following:

- Verify that sediment remedial actions in the Lower Fox River result in substantive reductions in water column and fish tissue PCB concentrations. The RODs identified water and fish tissue as key exposure media through which bioaccumulation may occur (see also Section 7.5.1.3).
- Verify that sediment remedial actions in the Lower Fox River result in substantive reductions of PCB loadings to Green Bay. Decreased loadings from the Lower Fox River will help facilitate natural recovery processes in Green Bay.

7.6.1.3 Characterize Bioaccumulation Pathways

As determined in the Baseline Risk Assessment (Retec 2002), the primary exposure pathway for humans and wildlife to become exposed to PCBs in the Lower Fox River is through consumption of PCB-contaminated fish. Therefore, the focus of the LTMP is to monitor risk reduction to humans and wildlife (including fishermen as well as fish-eating mammals and birds) as a result of the remedial action, by monitoring PCB concentrations in an appropriate selection of fish species, fish size/age, and preparation methods which are relevant to these receptors. Whereas PCB-related risks to both humans and wildlife are largely associated with fish consumption, improvements in water quality may have a shorter response time and possibly fewer confounding factors compared to fish tissue.

7.6.2 Water Quality Monitoring Plan

In general, water monitoring stations will be sited near the boundaries of the OUs such that the net PCB contribution from each OU, and the effectiveness of the remedy in each OU, can be evaluated. In addition, multiple water quality monitoring stations are sited in OU 2 and OU 5. The monitoring locations are consistent, to the extent possible, with stations occupied during past and ongoing monitoring programs. For example, water quality monitoring in OU 4 will be coincident with the USGS and LMMBS monitoring station at the Oil Depot gage.

7.6.2.1 Water Quality Monitoring Stations

Water column samples will be collected and analyzed at 1 upstream reference location in Lake Winnebago, 6 stations along the Lower Fox River (OUs 1-4), and 3 stations in Green Bay (OU 5), for a total of 10 stations. These stations are described below:

- Lake Winnebago (upstream reference station). Just above Neenah and Menasha Channels.
- OU-1. Downstream of LLBDM and above the first Appleton Dam.
- OU-2A. Reach between Lock 4 and Cedars Lock.
- OU-2B. Reach between Lock 5 and Rapide Croche Lock.
- OU-2C. Above Little Rapids Dam.
- OU-3. Above DePere Dam.

- OU-4. Near the USGS river gage (Oil Depot gage); approximately 1,300 meters upstream from the mouth, and beyond the influence of upstream transport of bay water under seiche conditions. This station will be co-located with a USGS station which is scheduled for water quality monitoring in 2005/2006.
- OU-5A. Zone II/Zone III Boundary
- OU-5B. Zone III South
- OU-5C. Zone III North

7.6.2.2 Water Quality Monitoring Schedule

During each scheduled monitoring year, sampling will be performed on a monthly basis for the entire year (12 sampling events total). The sampling schedule will be "systematic" in design (i.e., predetermined sampling at regular intervals), to provide representative and unbiased coverage. Specific runoff events will not be targeted but a representative range of flows will likely be captured during the course of the monitoring program. Baseline water quality monitoring is scheduled to begin in spring 2006.

During subsequent five-year monitoring events, water quality monitoring may be reduced or eliminated in favor of fish tissue monitoring since fish tissue is the primary medium of exposure to PCBs for humans and wildlife. For example, if fish tissue concentrations recover at a rate and magnitude consistent with ROD expectations, the scope of the water quality monitoring program (i.e., number of sampling stations and/or seasonal sampling frequency) may be reduced or eliminated. Alternatively, if fish tissue recovery trends fall significantly behind expectations, water column monitoring may be reinstated. A more detailed description of the conditions under which water column monitoring would be reduced, eliminated, or reinstated will be provided in the OMMP (60% Design submittal).

7.6.2.3 Water Quality Analytical Parameters

During each specified monitoring year, twelve rounds of water column samples (once a month for a year) will be collected at ten stations, for a total of 120 samples plus quality control samples. All water column samples will be analyzed for the following:

- PCB Congeners (209 total) by EPA Method 1668A (high-res GC/MS).
- Total Suspended Solids (TSS) by EPA Method 160.2.
- Total Organic Carbon (TOC) by EPA Method 415.1.
- Temperature and turbidity.

7.6.3 Fish Tissue Monitoring Plan

Fish monitoring stations include an upstream reference site (Lake Winnebago), six stations in the Lower Fox River, and one station in Green Bay (8 stations total). One sampling station is assigned to each OU, except OU 2 which has three sampling stations because of its length and dam controls. Exact locations will be determined in the field based on species availability, habitat, and seasonal migration patterns. Because of these variables, different species will be collected from different parts of the OUs.

7.6.3.1 Fish Tissue Monitoring Stations

Fish will be collected from the following locations:

- Lake Winnebago (upstream reference station).
- OU-1. Little Lake Butte de Morts.
- OU-2A. Reach between Lock 4 and Cedars Lock.
- OU-2B. Reach between Lock 5 and Rapide Croche Lock.
- OU-2C. Above Little Rapids Dam.
- OU-3. Reach above DePere Dam.
- OU-4. Reach from DePere Dam to about 1,000 meters upstream from the mouth, above the influence of bay water.
- OU-5 (Green Bay). Zone II/III (Inner/Middle Green Bay).

7.6.3.2 Fish Tissue Monitoring Schedule

Fish tissue samples are currently targeted to be collected between August 15 and September 15, 2006. Fish sampling will be conducted during this same seasonal window for all baseline and long-term monitoring events to minimize seasonal differences in fish tissue concentrations between monitoring years.

Monitoring will be discontinued when specific remediation goals have been achieved (i.e., attainment of specific target tissue levels which do not pose a risk to humans or wildlife). A more detailed description of the conditions under which monitoring would be terminated will be provided in the OMMP.

7.6.3.3 Fish Species and Target Size Ranges

Target fish species were selected based on a number of criteria:

- Presence of fish consumption advisories;
- Popular recreational fishery;

- Key species evaluated in Human Health or Ecological Risk Assessments (Retec 2002c);
- Common food source for upper-level animals (i.e., fish-eating mammals, birds); and
- Elevated PCB concentrations in recent monitoring data.

Five target fish species were selected to address three different monitoring objectives:

- Protection of human health (walleye, channel catfish);
- Protection of wildlife (carp, drum); and
- Early indication of river recovery (young gizzard shad).

All five fish species will be collected and analyzed during baseline and Year 0 monitoring events. In the post-construction period, however, fish tissue monitoring will be reduced to three species—a human health index (walleye), an ecological index (carp), and a young forage fish species (gizzard shad). Channel catfish and drum will be reserved as alternate species if collection of any of the three primary species becomes problematic.

7.6.3.4 Fish Tissue Analysis

For human health indicator species (walleye and channel catfish), fifteen individual specimens will be analyzed from eight different stations, for a total of 120 analyses for each species. For ecological indicator species (carp, drum, and gizzard shad), five composite samples will be prepared from eight different stations, for a total of 40 analyses for each species. Altogether, considering the sum of all replicates, stations, and species, 360 samples of fish tissue will be analyzed, not including quality control samples, during the baseline monitoring event. During subsequent long-term monitoring events, the monitoring program will consist of one human health indicator species and two ecological indicator species (including a forage fish species such as gizzard shad), for a total of 200 fish tissue analyses, not including quality control samples.

To ensure consistency with past and ongoing monitoring programs, analytical methods will follow procedures used by the Wisconsin State Lab of Hygiene (SLOH) to the extent possible. Specifically, fish tissue samples will be analyzed according to the following methods:

- Tissue Extraction by SLOH Method.
- PCB Aroclors by EPA Method 8082.
- Lipid Content by gravimetric method (EPA 2000).

In addition, walleye samples from Station OU 2C will also be analyzed for:

- Mercury (EPA Method 7471).

7.7 Schedule

The scheduling of various short-term (construction period) and long-term (post-construction period) monitoring programs is summarized on Figure 7-2. The remedial action is expected to take nine or more years to complete, depending on the scenario.

Pre-Construction Work. Prior to the remedial action, baseline monitoring of water and aquatic biota will be performed to establish existing conditions in the Lower Fox River and Green Bay, and to establish a basis of comparison for long-term monitoring during the post-construction period. Baseline water quality monitoring will also be performed during this time to support construction monitoring, and to establish the range of ambient turbidity conditions that may be encountered during construction.

Construction-Related Work. During the remedial action, water quality monitoring will be performed to control water quality impacts during construction. Sediment confirmation sampling will be performed to verify that dredging has resulted in removal of PCBs to the specifications of the contract documents and the ROD. Cap monitoring will be performed to verify: (1) caps are constructed to the depths and extents specified in the contract documents; (2) the source material for capping is uncontaminated; and (3) in-water capping activities cause no adverse water quality effects.

Construction Completion Work. At the completion of the remedial action (Year 0), a hydrographic condition survey will be performed to characterize the starting elevation of capped areas and to provide a basis to evaluate cap erosion in subsequent surveys. During Year 0, a round of water quality and aquatic biota sampling will also be performed to support the objectives of the Long-Term Monitoring Plan.

Post-Construction Work. In the post-construction period, cap performance monitoring will be conducted to ensure the physical and chemical integrity of the cap is maintained. Cap performance monitoring will initially be conducted more on a frequent basis, with completion of Year 0, Year 2, and Year 4 events to provide early feedback after the completion of the remedial action. Cap performance monitoring will then be reduced to ten-year or twenty-year intervals pending favorable results during the initial monitoring events (with contingency monitoring following flood events with 50-year recurrence interval or greater). Sampling of water quality and aquatic biota will initially be performed on a five-year cycle to monitor progress toward achieving project RAOs which are focused on reducing risks to humans and wildlife. When appropriate, cap monitoring and water/biota sampling can be coordinated to take place during the same year. It is recommended that both cap monitoring and water/biota sampling be conducted one year prior to the scheduled CERCLA five-year reviews, so that the most up-to-date information will be available to inform the process and to better scope future monitoring efforts and strategies.

8. SUMMARY OF COST ESTIMATES

The ROD for OU 3 through 5 and subsequent DEA presented preliminary cost estimates for the ROD Remedy. This Section presents a more detailed cost estimate for both the ROD and Optimized Remedy. The ROD Remedy cost estimate presented in this BODR was prepared in a "bottom up" fashion and did not rely significantly on the preliminary estimates presented in the ROD and DEA. The cost estimate for the Optimized Remedy was developed in the same fashion to provide comparable estimates between the two remedies.

The cost estimates presented in this Section include design, preconstruction, capital, annual operation and maintenance (O&M), and long-term monitoring costs. All pre-construction and construction costs were assumed to be present day (2005) values to provide a clear comparison of the actual costs. Long-term monitoring and maintenance costs are provided in terms of net present value, determined in accordance with USEPA guidance (EPA 1993, 2000). The cost estimates have been advanced to approximately a 30 percent design level for both remedy options at a similar level of detail.

8.1 Cost Estimating Framework

The project costs were divided into four major "Categories", including the following, as shown on Figure 8-1:

I. Pre-construction

II. Construction

III. Monitoring and Maintenance

IV. Non-Construction

Within each of these categories, numerous "tasks" and "subtasks" were identified representing the discrete project elements. Detailed costs for each task and subtask were then estimated in a "bottom up" fashion with consideration of labor, equipment, and materials.

To ensure consistency throughout the estimate, a standardized cost estimating template was developed in cooperation with the Agencies and Oversight Team as part of the Technical Work Groups. Furthermore, the cost estimate templates utilize a consistent schedule of rates for labor, equipment, and materials for each task.

8.2 ROD Remedy Cost Estimate

The ROD Remedy cost estimate has been updated from the estimate presented in the OUs 3 through 5 ROD to incorporate the latest developments, including the following significantly revised assumptions:

- Use of two dredges to reduce the project duration;
- Use of mechanical dredging and passive dewatering/amendment of sediments potentially subject to TSCA disposal requirements;
- Desanding (sand segregation) and regional beneficial use of segregated sands;
- In situ capping in some shoreline areas where dredging cannot be performed without adversely impacting the stability of the slopes;
- Elimination of annual removal/replacement of NR 213 drainage layer;
- 2-foot increase in the depth of NR 213 settling basin to accommodate the higher flow rate associated with using two dredges; and
- Use of sand covers as residuals management technique.

Table 8-1 presents a summary of the cost estimate for the ROD Remedy. Details of the framework and assumptions used for this estimate are provided in the following sections.

8.2.1 Cost Estimate Assumptions

In general, the ROD Remedy cost estimate is based on the assumption that the use of two dredges would be an effective and efficient means of performing the necessary dredging within a timeframe of approximately 10 years. Although this assumption was determined to be technically feasible by the Workgroups, the implementability is uncertain, given that such an operation has not been successfully implemented on a previous project of this magnitude. However, a project contingency cost was not included in the estimate, in order to provide a comparable estimate to the Optimized Remedy, which accounted for project uncertainties in the form of unit costs of individual items, as opposed to a percentage of the total project costs. As such, the ROD Remedy cost estimate is not considered conservative and actual costs could be significantly higher if the two dredge approach is initially implemented, and potentially discontinued as the project progresses.

This section provides details regarding the assumptions used to estimate the costs for the ROD Remedy. Similar assumptions were made in estimating the cost of the Optimized Remedy, with additional assumptions provided in Section 8.3. The Optimized Remedy Design Memo (Shaw/Anchor 2006b) presents the detailed cost worksheets used for the estimates.

Costs were computed by estimating both the labor and equipment required for various tasks. The following were the general assumptions that were made in developing the cost estimate:

- The majority of the work would be completed over two 12-hour shifts per day. The exception is the assumption that the shoreline capping in OU 3 would be completed over one 12-hour shift per day;
- Work would be performed 6 days per week; and
- The in-water work season was assumed to be 154 working days per year, over the 6-month (180-day) season.

The following assumptions were made when computing labor costs:

- Labor would be paid at Wisconsin prevailing wages, which include an hourly labor rate, plus a fringe rate to cover benefits;
- Overtime would be paid at 1.5 times the hourly labor rate, for any work over 40 hours per week; and
- The fringe rate would be paid for the total number of hours worked per week.

The following assumptions were made when computing equipment costs:

- Monthly rental rates were obtained from local equipment suppliers and area contractors. These rates were converted to a unit rate per shift, assuming 6 days of work per week, and 4 weeks per month; and
- All equipment was assumed to be rented, with the exception of the project consumables (including hydraulic dredge pipeline, return water pipeline, etc.), hydraulic dredges, and booster pumps, which would be purchased during initial mobilization and site preparation.

Major assumptions for each of the four cost categories outlined in Figure 8-1 are described below.

8.2.1.1 Mobilization and Site Preparation

Mobilization and site preparation costs include the work required to deliver equipment to the site, and to prepare all upland staging and disposal areas for the work. Because this is a multi-year project, costs for interim demobilization, winterization, and remobilization were included. Final demobilization and site cleanup costs were also included in this estimate.

The following mobilization and site preparation assumptions were made:

- The Shell Property would be utilized as the upland staging area. This area would require some level of clearing and grubbing and placement of a new impervious asphalt surface to prepare for the work;
- In addition, the staging area would require improvements including the installation of 600 feet of sheet pile wall to create a new bulkhead (with reinforcing tiebacks and backfill using on-site materials) to provide a barge berthing area for offloading of debris and sediments potentially subject to TSCA disposal requirements, as well as vessel mooring;

- Backfill material for the bulkhead will be imported from local sources (likely from suitable upland soil excavated from the Shell Property);
- An asphalt dewatering pad would be constructed at the Shell Property consisting of a geotextile, HDPE liner, a system of sumps, and 6 inches of asphalt paving;
- A sediment processing plant would be constructed at the Shell Property including desanding and water treatment facilities;
- Initial mobilization of the hydraulic dredges is assumed to require 12 weeks of labor and require equipment rental to move equipment and to setup the dredge lines and booster pumps;
- Final demobilization of the hydraulic dredge equipment and pipeline is assumed to require a total of 10 weeks;
- Interim demobilization assumes that most of the floating and land-based equipment (with the exception of the dredges purchased for the job) would be sent to other job sites in the off season, with no additional cost to the project; it is assumed that moving this equipment off site would be paid by the mobilization fee for the job to which they would be sent; and
- Costs have been included for the development of a disposal facility, including land purchase and an estimated host (siting) fee, based on available information.

8.2.1.2 Dredging, Disposal, and Capping

Dredging for the ROD Remedy includes hydraulic dredging in OU 2, OU 3, and OU 4, with mechanical debris removal and mechanical removal of sediments potentially subject to TSCA disposal requirements. Two dredges were assumed for dredging OU 4 under the ROD Remedy only, which would require the use of an upland surge tank feeding a single pipeline to the NR 213 settling basin. One dredge was assumed for OU 3 due to the technical difficulties with pipeline routes and operation of the surge tank, which would likely be located at the Shell Property in OU 4.

Under the ROD Remedy, capping of shoreline areas would be required where existing PCB concentrations exceed the 1 ppm RAL but cannot be dredged without adversely impacting the stability of the slopes. It was assumed that import cap material would be delivered to the staging area in OU 4 (the Shell Property) by a large-capacity (approximately 20,000 ton) material vessel. A small volume of dredging and disposal (beyond the required 1 ppm boundaries identified for remediation) was assumed necessary to provide deep-water access required to accommodate the large cap material delivery vessel. Following offloading at the Shell Property, the cap material would then be transferred, as needed, to smaller, shallow draft barges for mechanical placement in OU 3 and OU 4.

The following specific assumptions were made in developing the cost estimate:

- Debris would be removed as an initial dredging operation, with additional costs included for “on-call” debris removal as needed during full-scale dredging;
- Sediments potentially subject to TSCA disposal requirements would be removed through mechanical dredging. Lime would be added at 15 percent by weight to facilitate

transportation to the TSCA landfill. (Note: depending on the availability at the time of construction, other amendment materials may be substituted for lime, but lime was assumed for costing purposes);

- Truck traffic from the offloading site would be limited to 15 trucks per day based on previous experience with this type of work in and around residential areas. Each truck is assumed to have a capacity of 20 cy, which limits daily off-site transport from the offloading area to a TSCA landfill to 300 cy per day;
- Hydraulic dredging in OU 4 for the ROD Remedy would use two 12-inch dredges pumping at 5,000 gpm each. The two dredges would both feed to a 100,000 gallon surge tank located on the adjacent upland area (likely the Shell Property in OU 4). A mechanical agitation system would be used to maintain suspension of particles within the surge tank. In addition, an air diffuser system would also be used to maintain suspension of the fine-grained particles;
- One 12-inch dredge would operate in OUs 2 and 3 pumping at 5,000 gpm for the ROD Remedy;
- Large particles (gravel-sized and large) would be separated from the dredge slurry prior to entering the surge tank (or pipeline when surge tank is not required) by a mechanical screening / shaker system;
- Sand separation ("desanding") of the dredge slurry would be performed prior to transport to the disposal facility. Approximately 530,000 cy of sand would be removed under the ROD Remedy;
- The hydraulic dredge pipeline (18-inch-diameter) would be purchased once, and would be rotated (e.g. rolled) up to three times during the project to limit wear and extend its lifetime;
- Shoreline capping would be performed using mechanical equipment, assuming a 5 cy clamshell bucket. Caps were assumed to extend 75-feet from the shoreline, where appropriate, providing a safe offset for dredging so as to prevent undermining existing slopes;
- Capping would be performed over two shifts per day in OU 4 and one shift per day in OU 3 due to noise concerns in adjacent residential areas;
- Fuel charges were estimated for each activity based on the number of fueled equipment hours;
- Disposal facility costs include the labor required to operate the disposal facility, and costs for water treatment; and
- The costs associated with the potential use of a dewatering amendment added to the sediments removed from the NR 213 settling basin prior to disposal in the NR 500 final disposal facility was not included in this BODR cost estimate. However, as discussed in Section 4.1 the NR 500 disposal facility was sized to accommodate the anticipated volume of a dewatering amendment (assumed at 5 percent by weight) mixed with the sediment to achieve the required consistency prior to final disposal in the NR 500 landfill.
- Treated water would be pumped back to the river along the same pipeline route used for the hydraulic dredge.

8.2.1.3 Construction and Long-Term Monitoring

The construction and long-term monitoring tasks include all contractor- and owner-supplied monitoring during and after construction. Monitoring includes pre-dredge, progress, and payment bathymetric surveys, water quality monitoring, wastewater effluent quality monitoring, post-dredge confirmation sediment sampling and analysis, and disposal area environmental monitoring.

Contractor- and owner-supplied monitoring was estimated on separate worksheets so that overhead and profit could be treated differently for each of these activities (see Shaw/Anchor 2006b). Contractor labor rates, as described previously, assume prevailing wage rates for the State of Wisconsin. As such, an overhead and profit (O&P) assumption was made and applied as appropriate to these rates. Independent monitoring, on the other hand, was assumed to be provided by consultants. Labor rates for these activities were assumed by using billing rates typical of local consultants. On these worksheets, the O&P has been assumed to be 0 percent, because O&P is already built into the billing rates that were assumed.

Actual monitoring requirements will be developed through the collaborative workgroup process. Nonetheless, in order to develop a cost estimate for this BODR, certain "straw person" assumptions were made. These assumptions were as follows:

- Water quality monitoring during construction activities was assumed to be a tiered program with initially intensive monitoring during the startup or significant change of activities. Following a period of intensive monitoring without exceeding the set standards, the monitoring frequency would be reduced. See Section 7 for a complete description of the water quality monitoring program;
- Bathymetric survey costs were estimated based on a per-acre unit rate from previous experience on the river;
- Post-dredge surface sediment confirmation sampling and analysis was assumed to be required at the same frequency as RD investigations (approximately 1 core per 1.6 acres and composited as discussed in Section 7). The area of sampling would include the dredge area and the margins (e.g. the area at or above a significance level of 0.3, as defined in Section 2.3 and 7.4);
- Long-term monitoring costs include baseline pre-construction and post-construction monitoring of water quality and fish tissue, and sediment surface monitoring in OUs 2 to 5 as described in Section 7.6;
- Long-term monitoring costs include costs for monitoring at the disposal area;
- Long-term cap monitoring will include both physical integrity monitoring (bathymetry surveys and coring) as well as chemical analyses of surface sediment samples and core intervals; and
- Cap maintenance was conservatively assumed to be required over 5 percent of the area at four events in the future (2, 5, 10, and 30 years after construction). For each cap maintenance event, it was assumed that an armor layer larger than the original design would be placed.

8.2.1.4 Engineering and Construction Support

Engineering and construction support costs include the development of design documentation, plans and specifications, and work plans to complete the work. These costs have been estimated as a lump sum item, based on a review of similar projects. Construction support costs assumed two full-time inspectors on site throughout the course of the work, with additional allowance for a construction manager, engineer, and for administrative assistance.

8.2.1.5 ROD Remedy Cost Estimate

Table 8-1 presents a summary of the cost estimate for the ROD Remedy. The total estimated cost for the ROD Remedy is $580 million. Section 8.4 presents a comparison of these costs to the estimated cost of the Optimized Remedy.

8.3 Optimized Remedy Cost Estimate

The Optimized Remedy cost estimate has been developed to the same level of detail and with many of the same assumptions as the ROD Remedy estimate. The following are the significant differences from the ROD Remedy presented in the OUs 3 through 5 ROD:

- Use of one hydraulic dredge with mechanical dewatering;
- Mechanical dredging of approximately 24,000 cy for OU 2 and 6,000 cy for OU 3 in areas with restricted access. Dredged material would be transported via barge to the Shell Property staging area and offloaded hydraulically directly to the sediment processing facility;
- Truck transport of dewatered material to local landfill;
- Use of hydraulic dredging and mechanical dewatering of sediments potentially subject to TSCA disposal requirements;
- Desanding (sand segregation) and on-site (backfill of wharf at Shell Property) and regional beneficial use of segregated sands; and
- In situ capping of contaminated sediment in specific locations (where permanent stability and performance can be assured).

Additional details of the framework and assumptions used for this estimate are provided in the following sections.

8.3.1 Optimized Remedy Cost Estimate Assumptions

This section provides details regarding the assumptions used to estimate the costs for the Optimized Remedy. The Optimized Remedy Design Memo (Shaw/Anchor 2006b) presents the detailed cost worksheets used for the estimates.

As discussed above, the uncertainties associated with the Optimized Remedy have been inherently captured in the unit cost estimates for individual tasks. Cost uncertainties captured in the unit prices include the cost of mechanical dewatering and the conservative estimate of the beneficial use of segregated sand (also applied to the ROD Remedy).

The same general assumptions made for the ROD Remedy regarding labor, work schedule, and equipment were also made for the Optimized Remedy. Major assumptions for each of the four cost categories outlined in Figure 8-1 are described in Section 8.2 with the following exceptions.

8.3.1.1 Mobilization and Site Preparation

The following mobilization and site preparation assumptions were made:

- Similar to the ROD Remedy assumption, the Shell Property would be utilized as the upland staging area. However, a larger footprint will be required under the Optimized Remedy to accommodate the increase in process equipment, truck load out and decon areas, weigh scale and material staging stockpiles(see below);
- The Shell Property staging area would require improvements including the installation of 1,500 feet of sheet pile wall to create a new bulkhead (with reinforcing tiebacks and backfill) to provide a barge berthing area for offloading of debris and mechanically dredged sediments as well as vessel mooring; Initially, only a portion of the bulkhead length will be backfilled using soils from an on-site borrow pit (e.g. scraped from the Shell Property) to create a working pad for offloading equipment. During hydraulic dredging and desanding, additional fill materials (i.e. segregated sand) will be used to complete the bulkhead backfill and eventually replace the on-site soils excavated for preliminary backfill;
- Temporary, floating platform and mooring facilities (e.g., Flexifloats) may be necessary during the time that construction of the wharf is underway. A two year time-frame was assumed; and
- A sediment processing plant would be constructed at the Shell Property including a desanding, mechanical dewatering (plate and frame filter presses), and water treatment facilities.

8.3.1.2 Dredging, Disposal, and Capping

Dredging for the Optimized Remedy includes hydraulic dredging of non-TSCA sediment in OU 3, and OU 4, with mechanical dredging in OU 2 and a portion of OU 3 (approximately 30,000 cy total). A single hydraulic dredge was assumed for dredging under the Optimized Remedy. Sediments in OU 4 that are potentially subject to TSCA disposal requirements would also be removed with a single hydraulic dredge. Similar to the ROD Remedy, debris would be removed mechanically and offloaded at the Shell Property.

Similar to the ROD Remedy, import cap material would be delivered to the staging area in OU 4 (the Shell Property) by a large-capacity (20,000 ton) material vessel and subsequently transferred, to smaller, shallow draft barges for mechanical placement in OUs 2 to 5.

The following specific assumptions were made in developing the cost estimate:

- Sediments potentially subject to TSCA disposal requirements would be removed by hydraulic dredging and dewatered by mechanical filter press;
- TSCA sediment transport was assumed to be the same as under the ROD Remedy;
- Hydraulic dredging in OUs 3 and 4 for the Optimized Remedy would use one 12-inch dredge pumping at 5,000 gpm;
- Mechanically dredged sediments from OUs 2 and 3 would be transported via barge to the Shell Property and offloaded hydraulically directly to the sediment processing facility;
- All hydraulically dredged sediment would be mechanically dewatered by plate and frame filter press and transported via truck to the appropriate landfill (TSCA or non-TSCA);
- Sand separation ("desanding") of the dredge slurry would be performed prior to transport to the disposal facility. Approximately 218,000 cy would be removed under the Optimized Remedy;
- Capping would be performed over two shifts per day in OU 4 and one shift per day in OU 3 due to noise concerns in adjacent residential areas;
- Fuel charges were estimated for each activity based on the number of fueled equipment hours;
- Disposal facility costs include the labor required to operate the disposal facility, and costs for water treatment; and
- Treated water would be pumped back to the river along the same pipeline route used for the hydraulic dredge.

8.3.1.3 Construction and Long-Term Monitoring

- The assumptions regarding construction and long-term monitoring for the Optimized Remedy are generally consistent with the ROD Remedy, with the following specific exceptions:
- Long-term monitoring costs do not include costs for monitoring at the disposal area, since an existing permitted landfill was assumed rather than a newly constructed landfill assumed under the ROD Remedy;
- Maintenance of the capped areas was assumed to occur at 2, 5, 10, and 50 years after construction; and
- Long-term monitoring and maintenance costs were calculated on a present worth basis.

8.3.1.4 Optimized Remedy Cost Estimate

Table 8-1 presents a summary of the cost estimate for the Optimized Remedy. The total estimated cost for the Optimized Remedy is $390 million.

8.4 Comparison of ROD Remedy and Optimized Remedy Costs

Table 8-1 presented the estimated costs to perform the ROD and Optimized Remedies. The Optimized Remedy is estimated to cost approximately $190 million dollars less than the ROD Remedy. This comparison excludes the potential cost associated with the use of a dewatering amendment under the ROD Remedy, which could increase the cost by as much as $220 million, as discussed in Section 4.1.1.1. As discussed in Section 5.9, in addition to the difference in costs, the Optimized Remedy is more implementable than the ROD Remedy, due to the uncertainties with using two dredges with a single pipeline, the greater complexity of the ROD Remedy dredge plan, pipeline easement uncertainties associated with the ROD Remedy, and the limited local landfill capacity.

As discussed above, the cost estimate for the Optimized Remedy incorporated a number of conservative assumptions that may result in an overestimate of the final costs of implementing this remedy. That is, relatively high-end costs were used for some of the more significant cost elements, including sediment transport and disposal, and potential beneficial use. The Optimized Remedy cost estimate incorporated a relatively high-end unit cost to arrange and provide for beneficial use ($30/ton), even though many potential lower cost options for use could become available. Given this and other conservative assumptions, an overall project contingency as may be used in other cost estimating applications is not considered appropriate for the Optimized Remedy. Although the ROD Remedy captured the uncertainty in beneficial use costs, other significant technical uncertainties (most notably the use of two dredges with one pipeline and the local negotiations for pipeline easements and use of a relatively large portion of the available landfill space) are not easily accounted for in unit costs. Therefore the ROD Remedy unit cost in not considered conservative, as the Optimized Remedy cost is.

9. Identification Of Additional Stakeholder Outreach Activities

During the process of identifying appropriate sites for staging, dewatering, disposal and alternatives for beneficial use and transportation, all of the potential options were evaluated sequentially within the following categories;

- Initial Screening of Alternatives
- Threshold Criteria
- Implementability Criteria
- Modifying Criteria

The top alternatives that emerged from this process are described in this BODR, but further evaluation will occur during subsequent design phases. It is envisioned that further evaluation, selection and design will require stakeholder outreach activities to determine social and political acceptance of the proposed alternatives.

9.1 Staging/Dewatering Sites

The initial review of potential staging areas in OU 3 and 4 was limited to those identified in the DEA Report (RETEC 2003). In subsequent design phases, following approval of this BODR, the design team will be performing further evaluation of the Shell Property and alternate sites for logistical efficiencies and cost effectiveness.

Stakeholder activities will include continued communications with GP to identify the time frame over which the Shell Property may be available for use as a staging facility. Additional stakeholder activities will include continued communication with property owners and local real estate agents to determine if a cost effective alternative exists for the staging area required during remedial activities.

9.2 Disposal Sites

This BODR currently identifies three potential disposal sites for non-TSCA material and two landfills for disposal of dredged sediments from OUs 2 to 5 that are potentially subject to TSCA disposal requirements. Evaluation has been performed through initial implementability reviews; ability to receive PCB impacted sediments, total site acreage compared to total acreage (when appropriate), liner type, and surrounding land use. The next step in the evaluation process is to determine the level of social and political acceptance for each of the alternatives, and to identify the potential for project delays caused by public resistance and/or permitting hurdles.

9.2.1 Non-TSCA Disposal Alternatives Stakeholder Activities

Three potential NR 500 landfill disposal sites were identified for non-TSCA material removed during the proposed remedial activities;

- Brown County South
- Brown County VandeHey
- Onyx Hickory Meadows Landfill

The proposed stakeholder activities will center on public meetings and public education efforts. Additionally, stakeholder activities will include discussions with area officials, regulatory agencies and continued work group meetings with the appropriate government participants (i.e., WDNR, USEPA, etc.) to determine siting/permitting requirements. The stakeholder activities for the Onyx Landfill facility will consist primarily of evaluating pricing and transportation options, and review of applicable regulatory requirements. In addition, as described elsewhere in this report, evaluation of other alternative disposal sites for non-TSCA sediment will continue during design, and stakeholder activities may occur with respect to such sites.

9.2.2 TSCA Disposal Alternatives Stakeholder Activities

Potential TSCA disposal alternatives were identified for sediments dredged from OU 4 that may potentially be subject to TSCA disposal requirements include:.

- EQ Wayne Disposal, Belleville, Michigan
- Peoria Disposal Co., Peoria, Illinois
- Other authorized TSCA disposal location

The two existing TSCA landfill sites closest to the Fox River are located in Belleville, Michigan and Peoria, Illinois. The stakeholder activities for these two sites will consist primarily of negotiating pricing and transportation contracts, and review of applicable regulatory requirements.

9.3 Beneficial Use Alternatives

Beneficial uses of suitable dredged material commonly include shoreline stabilization, habitat development, beach nourishment, parks and recreation, agriculture uses and construction/industrial uses. Potential beneficial use alternatives are described in this BODR, but further technical evaluation is required to determine data gaps. It is envisioned that selection and design will require stakeholder outreach activities to determine social and political acceptance of the proposed alternatives. The proposed stakeholder activities will center on public meetings and education efforts, discussion with area officials and continued work group meetings with the appropriate government participants (i.e., WDNR, USEPA, USFWS, etc.)

9.4 Transportation

Transportation as described within this BODR includes a number of proposed transport alternatives; pipeline, barge and truck. Beyond the technical feasibility, implementability and cost issues, each of the proposed transportation alternatives has potential social and political acceptance issues. The proposed stakeholder activities will center on public meetings and education efforts, discussion with area officials and continued work group meetings with the appropriate government participants (i.e., WDNR, USEPA, etc.)

9.5 Future RD Milestones

The Administrative Order on Consent governing the RD process provides that the Agencies and the Participating Companies, after approval of this BODR, will together begin stakeholder outreach efforts. These stakeholder outreach efforts will include the stakeholder discussions and the additional evaluations identified above. The Participating Companies will continue to work with the Agencies through the collaborative work group process to manage and conduct these stakeholder outreach activities.

The next major written deliverable in the RD process is the "Preliminary Design" report or "30-Percent Design" (so called because it is to be submitted when the design is approximately 30 percent complete). Although the Preliminary Design report is the next major written deliverable, the Administrative Order on Consent provides that portions of that report that are completed earlier will be submitted to the Agencies earlier. The Preliminary Design report will 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 (2004 and 2005) 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;
- A "Sediment Removal Verification/Capping Plan" including the proposed cleanup verification methods and a plan for compliance with ARARs;
- Outline of required specifications;
- Proposed siting/locations of processes/construction activity;
- Proposed disposal locations based upon effectiveness, implementability and cost;

- A 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;
- A preliminary construction schedule, including contracting strategy;
- Any significant new information from other projects and activities on the river (e.g., OU 1 activities) and elsewhere; and
- A draft adaptive management plan for the Remedial Action.

As described above, various uncertainties in the RD have the potential to delay the project, increase costs, or even make the project infeasible. These uncertainties include the availability of landfill space (especially for the ROD Remedy, which will require two disposal locations), the question of whether the two hydraulic dredges planned for the ROD Remedy in OU 4 will work as efficiently as planned, and the siting of the pipeline. The stakeholder outreach activities described in this section will attempt to eliminate some of the uncertainty involving both social and political acceptance of the proposed design components.

10. References

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