9 Detailed Analysis of Remedial Alternatives

This section presents the detailed analysis of individual remedial alternatives for the river reaches and Green Bay zones that were developed in Section 7 of this FS Report. A total of seven possible remedial alternatives (Alternatives A through G) are compared to nine evaluation criteria designed to address CERCLA remediation requirements. Figure 9-1 provides a schematic view of the detailed analysis as described in the EPA RI/FS Guidance (EPA, 1988). As described in the EPA RI/FS Guidance, the detailed analysis for individual alternatives consists of the following three sets of analysis involving nine evaluation criteria:

- **Threshold Criteria**
  - Overall protection of human health and the environment
  - Compliance with ARARs

- **Balancing Criteria**
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility and volume through treatment
  - Short-term effectiveness
  - Implementability (technical and administrative feasibility)
  - Cost

- **Regulatory/Community Criteria**
  - State acceptance
  - Community acceptance

These nine evaluation criteria are intended to provide a framework for assessing the risks, costs and benefits for each remedial alternative, individually. The next step, conducted in Section 10, is a comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion and action level, and to identify the key tradeoffs between them.

9.1 Description of the Detailed Analysis Process

This section describes the detailed analysis process. Subsections are organized according to the primary criteria introduced at the start of this section. The evaluation is accomplished by considering each remedial alternative in terms of the criteria. With respect to the Balancing Criteria, the evaluation is conducted by proposing a number of questions directly related to each criteria, as a means of considering and thoroughly evaluating the river reach and Green Bay zone alternatives. In summary, the seven generic remedial alternatives developed for the Lower Fox River and Green Bay include:

A. No Action,
B. Monitored Natural Recovery and Institutional Controls,
C. Dredge and Off-site Disposal,
D. Dredge to On-site CDF,
E. Dredge and Thermal Treatment,
F. *In-situ* Cap to Maximum Extent Possible, and
G. Dredge to CAD site.

Sections 9.2, 9.3, and 9.4 describe the Threshold Criteria, the Balancing Criteria, and the Regulatory/Community Acceptance Criteria, respectively. However, the regulatory/community acceptance criteria will be addressed during the public comment period as described in Section 9.4.

9.2 Threshold Criteria

Threshold criteria serve as essential determinations that should be met by any remedial alternative in order to be eligible for selection. They serve as primary project goals for a remediation project. The threshold criteria are primarily addressed through the development of the remedial alternatives in Sections 6 and 7, and within the context of the detailed risk assessment in Section 8.

9.2.1 Overall Protection of Human Health and the Environment

The criterion, Overall Protection of Human Health and the Environment, is first addressed in Section 7 of this FS Report through the identification of the methods used to reduce the potential for adverse exposures to contaminated sediments. Section 8 of this FS Report continues the discussion of protecting human health and the environment in a detailed risk analysis for each of the remedial alternatives.

As discussed in Section 8, the primary risk to human health associated with the contaminated sediments is consumption of fish. The primary risk to the environment is bioaccumulation of PCBs from the consumption of fish, or direct ingestion/consumption of sediments for invertebrates. Protection of human health and the environment is achieved to varying degrees for each remedial alternative by selecting protective SQT risk levels, remedial action levels, and response actions. In this section, protection of human health and the environment is evaluated by residual risk in surface sediments using three lines of evidence:

- The projected number of years required to reduce PCB sediment loads and improve surface water quality based on residual PCB concentrations in surface sediments (surface-weighted averaging after completion of a remedy);

- The projected number of years required to consistently reach safe consumption of fish; and

- The projected number of years required to consistently reach surface sediment concentrations protective of fish or other biota.

The residual concentrations and duration of residual risk will be dependent upon the sediment action level selected for a particular alternative (detailed in Section 10). For this evaluation, the residual risk associated with each remedial alternative is provided in the screening tables under "Magnitude and Type of Residual Risk," and the values presented in these tables are for recreational anglers and carp-eating carnivorous birds and mammals. A summary of estimated "overall protection of human health and the environment" for each alternative is presented in Section 8.

The alternative-specific risk assessment (presented in Section 8 of the FS) estimated the number of years to consistently reach protective human health and environment thresholds after completion of a remedy. The term "consistently met" refers to the last time the predicted model results exceed the protective threshold in the modeled 100-year time frame. Several different receptors, risk levels, and media were presented, each with a different sediment threshold concentration. In order to continue forward with evaluations of risk in Sections 9 and 10 of the FS, a total of four human health and two environmental thresholds (based on fish tissue levels) were carried forward in the FS to facilitate risk comparison between alternatives and action levels. These key remedial thresholds include:

- **Human Health:** recreational angler, RME, HI is 1.0 (noncancer) for walleye (288 μg/kg PCBs);

- **Human Health:** recreational angler, RME, 10^{-5} cancer risk level for walleye (106 μg/kg PCBs);

- **Human Health:** high-intake fish consumer, RME, HI is 1.0 (noncancer) for walleye (181 μg/kg PCBs);

- **Human Health:** high-intake fish consumer, RME, 10^{-5} cancer risk level for walleye (71 μg/kg PCBs);

- **Environmental Health:** NOAEC carnivorous bird deformity from carp (121 μg/kg PCBs); and

- **Environmental Health:** NOAEC piscivorous mammal from carp (50 μg/kg PCBs).

These remedial thresholds represent fish tissue concentrations that are protective of human health and biotic receptors. Residual surface sediment concentrations required to meet these thresholds were predictive elements included in the PCB transport and bioaccumulation models used in the Lower Fox River and Green Bay. Outputs of the model were expressed as the number of years required to meet the protective fish tissue levels (based on residual sediment concentrations of an action level).

9.2.2 Compliance with ARARs and TBCs

Section 4 of this FS Report introduces the federal and state Applicable or Relevant Appropriate Requirements (ARARs) (Tables 4-2 and 4-3). Some of the listed ARARs and TBCs identify guidance and reference documents that apply to the management of the impacted sediments and the construction of containment structures in aquatic environments. The screening conducted in this section is for those ARARs and TBCs that relate to actions taken to implement the remedial alternatives.

Approval for, and performance of, the remedial alternatives will require that the actions taken comply with the ARARs and TBCs, to the extent practicable. The following subsections provide a summary of these issues with respect to: chemical-specific ARARs/TBCs, action-specific ARARs/TBCs, and location-specific ARARs/TBCs.

Chemical-specific ARARs/TBCs

Chemical-specific ARARs/TBCs apply to elements of the remedial alternatives which relate to the management of PCBs. The following subsections provide a summary of the issues related to compliance with chemical-specific ARARs/TBCs applicable to sediment remediation and the measures to be employed to attain compliance. For the purposes of this FS, there are no chemical-specific ARARs related to the removal and/or management of Lower Fox River sediments. Only chemical-specific TBCs exist.

Surface Water Quality. ARARs/TBCs for this area relate to maintaining surface water during remedial actions and long-term goals of achieving surface water quality after remedy completion. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin State Water Quality Criteria.** Wisconsin's surface water quality criteria (NR 100) are TBCs for a sediment remediation project. Water quality criteria are intended to be protective of both human health (through fish tissue) and the environment (wildlife).

- **Federal Clean Water Act.** Since the project area includes "water of the United States," surface water quality criteria apply. However, EPA has approved Wisconsin's water quality criteria as compliance standards.

Sediment Quality. The state of Wisconsin has the authority to calculate sediment quality criteria on a site-specific basis. However, for the purposes of this RI/FS, state surface water quality criteria were the valued endpoints of concern for long-term protection of human health and the environment instead of sediment quality. Water quality criteria are considered TBCs for the project. Sediment concentrations that are protective of human and biological endpoints were predicted through transport and bioaccumulation models for surface water and residual fish tissue levels.

Location-specific ARARs/TBCs

Location-specific ARARs/TBCs apply to certain types of remedial alternatives, many related to site-specific development and disposal restrictions (i.e., navigational constraints). The following subsections provide a summary of the issues related to compliance with location-specific ARARs/TBCs and the measures to be employed to attain compliance.

CDF Construction (Floodplain or In-water). ARARs/TBCs for this area relate to construction requirements, siting, and control measures to minimize impacts to the environment. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin Statutes Chapter 30 - Permit in Navigable Waters.** A bulkhead line is required prior to placing deposits in navigable waters. If a legislative bulkhead line or lakebed grant is issued, then these areas cease to be waters of the state and the title is transferred to a local municipality.

- **TBCs for Placement of PCB Sediments in CDFs.** CDF construction within bulkhead lines or lakebed grant areas could not be approved under the waste management program siting process of licensed landfills, but could be approved under a low-hazard waste exemption in the waste management program statutes (but likely limited to non-TSCA dredged material).

Upland Disposal Facility Construction. ARARs/TBCs for this area relate to construction and disposal requirements for sensitive areas. Specific approaches include:

- New facility construction will be located outside of navigable waters and floodplains as permitted by the WDNR waste management program (Lynch, 1998).

- Any off-site licensed landfill disposal site would have to comply with codified locational restrictions, including setback requirements from surface waters and floodplains.

Action-specific ARARs/TBCs

Action-specific ARARs/TBCs apply to implementation of the remedial alternatives. The following subsections provide a summary of the issues related to compliance with action-specific ARARs/TBCs and the measures to be employed to attain compliance.

Dredge and On-site Fill. ARARs/TBCs for this area relate to removal of sediments and the placement of sediments in a CDF or CAD site, or placement of a cap. The requirements specifically relate to protection of water quality, aquatic and wildlife habitat, and wetland areas. Specific approaches identified to address these ARARs/TBCs include:

- **Federal 33 USC 403, 33 CFR 320 through 330, and 40 CFR 230 - Excavation or Dredging of Contaminated Sediments.** Dredge and fill activities must comply with Section 10 of the Rivers and Harbors Act, Sections 301 and 404 of the Clean Water Act, and USACE regulations.

- **TBCs for Dredging and Filling of Water Bodies:**

  - WDNR 1990 Report of the Technical Subcommittee on Determination of Dredge Material Suitability of In-Water Disposal: specific habitat and wetland areas will be identified for each of the cap or CDF locations to allow for the development of protective measures and other compensatory actions.

  - Proposed capping of sediments with concentrations of 50 mg/kg or greater has not been perceived by the EPA as providing adequate protection to human health and the environment.

  - The EPA Wetlands Action Plan requires no net loss of remaining wetlands.

PCB-contaminated Media. ARARs/TBCs for this area relate to proper management of the PCB-contaminated sediments including handling and disposal. Specific approaches identified to address these ARARs/TBCs include:

- **Federal TSCA (40 CFR 761).** Remedial activities involving TSCA-level sediments (less than 50 ppm PCBs and defined as PCB waste) will employ protective features to provide containment so as to prevent releases. Any ARARs specific to TSCA would be limited to PCB wastes with greater than 50 ppm concentrations. For dredged material with PCB concentrations less than 50 ppm, state rules apply, but TSCA does not.

- **TBCs for Handling of PCB-contaminated Media.** EPA concurrence is required to dispose of dredged materials containing PCBs at concentrations greater than 50 mg/kg in Wisconsin landfills (Adamkus, 1995):

  - With EPA approval, WDNR has authority to regulate disposal of dredged materials containing concentrations less than 500 mg/kg; and

  - Disposal facility operations plan must be modified prior to upland acceptance of PCB dredged materials with concentrations greater than 50 mg/kg.

Dredged materials that are placed within a facility are subject to the regulatory authority of the WDNR Waste Management Program (Lynch, 1998).

Proposed capping of sediments with concentrations of 50 mg/kg or greater has not been perceived by the EPA as providing adequate protection to human health and the environment.

Surface Water Quality. ARARs and TBCs for this area relate to discharges to surface water from dredging operations, in-water construction, or wastewater resulting from sediment dewatering. Specific approaches identified to address these ARARs/TBCs include:

- **NR 200 WAC, NR 212 through 220 WAC - Wisconsin Pollution Discharge Elimination System (WPDES).** A Construction Site Stormwater Discharge Permit is required when construction activities disturb greater than 5 acres of land.

  Discharge limitations for the Lower Fox River Deposit N WPDES Permit included, but were not limited to:

  - TSS not to exceed daily maximum concentration of 10 mg/L (monthly average of 5 mg/L);
  - PCBs daily total discharge mass limits not to exceed 0.0036 pounds;
  - PCBs daily total discharge concentration limit not to exceed 1.2 μg/L per day; and
  - Other parameters included: heavy metals, select PAHs, pesticides, dioxins, pH, ammonia, BOD, and oil/grease.

- **NR 207 WAC - Water Quality Antidegradation.** Discharge of effluent water cannot contain COC concentrations which exceed concentrations found in the Lower Fox River.

- **Federal TSCA (40 CFR 761).** Remedial activities involving TSCA-level sediments (less than 50 ppm total suspended solids) must monitor:

- Dissolved oxygen concentrations,
- Flow rates,
- Thermal properties of effluent and receiving waters, and
- pH.

In Section 761.50(a)(3), no discharger may discharge effluent containing PCBs to a treatment works or to navigable waterways unless the PCB concentration is less than 3 μg/L in accordance with an NPDES permit.

Air Emissions. ARARs for this area relate to air emissions from remedial activities. Specific approaches identified to address these ARARs include:

- **NR 157 WAC - Management of PCBs and Products Containing PCBs.** Facilities used for the incineration of PCBs require written approval from the WDNR prior to being established.

  Facility must meet the minimum requirements of the following operational parameters:

  - Dwell time (2 seconds),
  - Temperature (2,000 °F),
  - Turbulence, and
  - Excess oxygen (3%).

  Facility must have scrubber to remove hydrochloric acid from exhaust gas.

- **NR 400 through 499 WAC - Air Pollution Control.** Depending on location and size of the thermal treatment unit, specific maximum particulate concentrations are regulated.

- **Clean Air Act, 40 CFR Part 761 - PCB Storage and Disposal.** PCB air emissions from incineration (i.e., thermal treatment) cannot exceed 0.01 gram PCB per kg of PCB treated.

- **Clean Air Act, 40 CFR Part 50.** Establishes ambient air quality standards for the protection of public health.

Upland Disposal Facility Construction. ARARs/TBCs for this area relate to construction and disposal requirements, siting, and control measures to minimize impacts to the environment. Disposal in a solid waste landfill is applicable to both non-TSCA level and TSCA-level PCB-contaminated dredged material. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin Statutes, Chapter 289 - Landfill Siting and Approval Process.** Disposal of dredged material in a licensed solid waste landfill is subject to the landfill approval process (Chapter 289 Statutes and Chapters NR 500 to 520 WAC).

  Specific design and construction requirements for a new solid waste landfill (or a "monofill" dedicated specifically to PCB sediments) are found in NR 504. WDNR has indicated that these requirements may also apply to the construction of an upland confined disposal facility (also described as a "wet" landfill).

  If temporary passive dewatering ponds are used, the performance requirements of Chapter NR 213 ("Lining of Industrial Lagoons and Design of Storage Structures") may apply. Alternatively, if WDNR decides to regulate passive dewatering ponds as a "solid waste processing facility," the requirements of the NR 500 series of rules may apply.

  No licensed hazardous waste landfills (Chapter 291 Statutes and NR 600 to 690 WAC) currently exist in the state of Wisconsin. However, permit requirements and the siting process would be similar to the solid waste landfill process.

  Solid wastes may be exempt from landfill siting requirements of WAC NR 500 through 520 if a "new" (i.e., treated material) is produced and meets the low-hazard exemption standards.

- **Wisconsin Statutes, Chapter 289 - Low-hazard Waste Grant of Exemption Disposal Site Process.** Low-hazard waste grant of exemption must meet authority (Section 289.43(8), Statutes) and public meeting requirements (Section 289.54, Statutes) set forth in state regulations.

  Placement in a low-hazard exemption disposal site applies to non-TSCA level dredged material only.

Transportation and Handling. ARARs/TBCs for this area relate to the transportation and handling of PCB-containing sediments during remedial activities. Specific approaches identified to address these ARARs/TBCs include:

- **49 CFR Parts 172 and 173 - General Requirements and Provisional Shipping Requirements for PCB-containing Material.** Transport vehicle transporting greater than 1,001 pounds of PCB waste must display Class 9 placards.

- **TBCs for Transportation of PCB-contaminated Media.** Establishes city, county, and state highway weight restrictions.

Worker Safety. ARARs for this area relate to protection of workers that are exposed, or potentially exposed to, hazardous materials. Specific approaches identified to address these ARARs include:

- **29 CFR Part 1910 - Occupational Safety and Health Administration:**

  - 1910.120(e)(3) and 1910.120(f) - Workers with such actual or potential contacts will be required to conform to the standards for hazardous material workers including participation in a medical monitoring program and current certifications for training in hazardous materials exposures.

  - 1910.132, 1910.134, and 1920.138 - Personal protective equipment (PPE) will be employed to ensure that workers are not exposed to adverse conditions during the work.

  - 1910.120(h) - Real-time monitoring will be conducted to ensure that work zones are properly delineated and that workers are wearing the proper PPE.

  - 1910.95 - Noise levels that exceed an 8-hour time-weighted average (TWA) of 85 decibels require hearing protection.

  - 1910.120(m) - Work areas will have adequate lighting to allow workers to identify hazards.

  - 1910 Subpart S - All electrical power must have a ground fault circuit interrupter and be approved for the class of hazard.

- 1910.147 - Operations where the unexpected energization or startup of equipment or release of stored energy could cause injury to personnel will be protected by the implementation of a lockout/tagout program.

- 1910.21 through 1910.32 and 1910.104 through 1910.107 - Requirements to help prevent falls will be implemented.

- 1910.151(c) - Operations involving the potential for eye injury, splash, etc., must have approved eyewash units locally available.

Effects of EPA-initiated Cleanups on ARARs

An EPA-led cleanup under CERCLA authority would not have to formally comply with Wisconsin procedural regulatory requirements for any dredging, storage, dewatering, or disposal activities that occurred within the limits of the project area. The limits of the project area would be defined in the proposed cleanup plan, but would closely conform to the limits of contamination. EPA's cleanup plans would have to consider and include the substantive requirements of state regulatory codes.

Any costs associated with a cleanup, such as dewatering, storage, handling, or disposal that took place outside of the defined limits of the project area would have to comply with all state regulatory requirements.

9.2.3 ARARs Applicable to Process Options Included in the Remedial Alternatives for the River and Bay

The specific remedial alternatives presented in Section 7 for each river reach and Green Bay zone are developed from the retained process options and technologies identified in Section 6. The ARARs and TBCs presented above in Section 9.2.2 are applicable to at least one process option used in the remedial alternatives. The No Action and Institutional Control alternatives are also evaluated here since these alternatives do not rely on other process options. The following subsections present a summary of significant ARARs and TBCs that must be addressed prior to and during the remedial work.

No Action

The No Action alternative has one primary TBC that relates to this alternative. The Water Quality Standards for Wisconsin Surface Waters define water use for protection of public health and propagation of fish, shellfish, and wildlife. These standards will be used over time to monitor the changing (diminishing) concentrations of PCBs in the Lower Fox River and Green Bay.

Monitored Natural Recovery/Institutional Controls

Concerning compliance with ARARs and TBCs, the MNR and Institutional Controls alternative is similar to the No Action alternative. The Water Quality Standards for Wisconsin Surface Waters will be used as TBCs to monitor surface water for the changing concentration of PCBs in the Lower Fox River and Green Bay. Other important ARARs/TBCs include fish consumption advisories which limit the consumption of fish containing PCBs by sensitive populations and institutional controls in which limitations or restrictions are placed on recreational and irrigation usage.

Containment

The containment technology involves *in-situ* capping of the river sediments with a synthetic liner, or a layer of sand, clay, or rock. Most of the ARARs/TBCs for the river reach alternatives that include capping are similar to CDF disposal alternatives. In addition, permits are required prior to filling any navigable water (Wisconsin Statute Chapter 30). Other important TBCs include the permanence of the cap when factoring in the cap thickness, river velocity, and the scouring effects of ships and boats passing over the cap. The containment process option is in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Removal

There are two removal technologies utilized in the dredging alternatives: hydraulic dredging and mechanical dredging. The ARARs/TBCs that are directly related to the removal of sediment from the Lower Fox River and Green Bay are the same for both removal technologies and can be placed into two groups: protection of surface water (NR 322, 200, and 220 through 297 WAC) and permits and fees to remove sediment (NR 346 and 347 WAC). The surface water ARARs/TBCs limit the discharge of PCBs and TSS into the receiving water bodies so that the water quality is not adversely affected. The removal process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Ex-situ Treatment

Thermal treatment is a process option retained for most of the river reaches and bay zones. ARARs specific to this technology relate to the air emission and permitting requirements of thermal treatment units (40 CFR 701 and NR 400 through 499 WAC). In addition, there are performance requirements of the thermal unit from NR 157 WAC that the thermal unit must meet in order to efficiently treat PCB sediments. The *ex-situ* treatment process option is in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Dewatering and Water Treatment

There are three types of dewatering technologies utilized for the dredging alternatives. These include mechanical dewatering, passive dewatering, and solidification. There is also effluent water from the mechanical and passive dewatering technologies that must be managed. The WPDES permit requirements (NR 200 and 220 through 297 WAC) sets forth requirements for the discharge of water to POTWs and to navigable waters (i.e., Lower Fox River). Permits for previous remedial activities on the Lower Fox River provide an indication of the treatment requirements to discharge effluent water to the Lower Fox River or a POTW. Another requirement of the WPDES permit is the Construction Site Stormwater Discharge Permit which will be required for the construction of dewatering ponds. Another potential important ARAR (NR 108 WAC) involves the construction of a wastewater treatment facility specifically to treat water from remedial activities. This ARAR requires WDNR review of wastewater treatment facility designs and specifications. The passive dewatering ponds are also managed under the wastewater treatment ARAR (NR 213 WAC) which sets effluent permit limitations associated with wastewater treatment facilities. There are no ARARs at this time that pertain to the solidification of dredged materials other than general construction ARARs, such as OSHA requirements, which are applicable for each process option. The dewatering and water treatment process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Disposal

There are two primary disposal options of PCB sediments removed from the Fox River and Green Bay. These include in-water disposal (i.e., the construction of a CDF or CAD site) and disposal in an upland landfill or newly constructed landfill for TSCA and non-TSCA level sediments. A low-hazard waste grant of exemption landfill can also be considered for non-TSCA level dredged material. ARARs/TBCs specific to this process option include the siting requirements for a landfill (Wisconsin Statutes Chapter 289) and obtaining lakebed and riverbed grants for CDF constructions from the Legislature and riparian landowners. There are also general design requirements for in-water construction (NR 322 WAC) that must also be met. General disposal requirements of PCB-containing dredged material are simplified with the agreement between the EPA and WDNR for placement of TSCA-level PCB-containing material (greater than 50 ppm PCBs) in a state-licensed landfill. The agreement allows the placement of PCB-containing material up to 500 mg/kg in an NR 500 WAC-regulated landfill as long as the landfill operations permit is modified. However, only public municipal landfills receive long-term liability protection for accepting PCB-impacted dredged material. This TSCA waiver agreement is not applicable to CDF or CAD sites. Placement of dredged material into CDFs could be approved under the low-hazard waste grant of exemption process. The disposal process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Transportation

There are three primary transportation methods for PCB sediment upland disposal alternatives. These include trucking of dredged material to a disposal facility, pumping of sediments to a dewatering and disposal facility, and barging of dredged sediments to a dewatering/treatment location. ARARs and TBCs that are important to this process option include the requirements to prevent spills and releases of PCB materials (NR 140 and 157 WAC). The following two ARARs are applicable only to the trucking of dredged material to a disposal facility. The Department of Transportation (DOT) has detailed requirements on the shipping of PCB materials. NR 157 WAC also has shipping requirements that include licensing of transporters of PCBs as transporters of hazardous wastes. The transportation process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative. ARARs and TBCs related to in-water transportation activities (i.e., piping and barging) include the protection of surface water (NR 322, 200, and 220 through 297 WAC). The surface water ARARs/TBCs limit the potential discharge of PCBs into receiving water bodies from potential barge overflows or pipeline breaks.

9.3 Balancing Criteria

Balancing criteria are included in the detailed analysis of alternatives because these five variables (long-term effectiveness, reduction, short-term effectiveness, implementability, and cost) are important components that often define the major trade-offs between alternatives. They serve as important elements of project goals that require careful consideration for successful implementation and long-term success of a remediation project. The five balancing criteria are evaluated for each remedial alternative in Tables 9-1 through 9-8 for each river reach and Green Bay zone, respectively. Detailed information pertaining to the residual risk for each remedial alternative is presented in Section 8. The following subsections provide a description of the criteria evaluated in this portion of the detailed analysis.

9.3.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence provides a means of evaluating the final risk at the site where remedial work has been completed. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of each remedial alternative and the risks associated with the untreated residuals. The following questions were used to evaluate the long-term effectiveness of each alternative:

- What residuals remain after completion of the remedy? Examples of residuals include solid residues after thermal treatment, sediments that spill from trucks and machinery, suspended solids during removal, and unremoved sediments with concentrations of COC above the cleanup goals.

- What is the magnitude of the residual risk?

- What institutional and/or engineering controls are needed?

- Are the controls reliable?

- What are the operations and maintenance requirements?

9.3.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction of toxicity, mobility, or volume through treatment provides a means of evaluating the permanence of each remedial alternative in reducing the toxicity, mobility, or volume of PCBs within the river and bay sediments. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of the alternative in destroying, reducing the mass, immobilizing, or reducing the volume of PCBs. The following questions were used to evaluate the long-term effectiveness of each alternative:

- Is the treatment portion of the remedy reversible?
- How does the remedy address toxicity, mobility, and volume?
- To what extent are COCs destroyed?
- Does the remedy rely on treatment or containment?

9.3.3 Short-term Effectiveness

Short-term effectiveness provides a means of evaluating the risk at the site while remedial work is being completed. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of each remedial alternative as they relate to risks posed to on-site workers, nearby residences, and downstream resources associated with the untreated residuals. The following questions were used to evaluate the short-term effectiveness of each alternative:

- What are the major risks to community, and what are the applicable control procedures?
- What are the major risks to remediation workers, and what are the applicable control procedures?
- What are the environmental impacts during construction and implementation of the remedy?
- What is the estimated duration of the remedial action?

9.3.4 Implementability

Implementability refers to the technical and administrative feasibility of implementing the remedial alternative. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the necessary services, supplies, permits, approvals, fees, and physical requirements that must be met to execute the alternative. The following questions were used to evaluate the feasibility and effectiveness of each alternative during implementation:

- Can the technology reliably meet cleanup goals? This criteria is also addressed in Section 7 of this FS Report.
- Are there site-specific technology limitations? The site-specific limitations are addressed for each alternative as described in Section 7 of this FS Report.
- What are the major uncertainties with implementation of the remedy?
- Can effectiveness of a remedy be monitored?
- Is a backup remedy necessary and implementable?
- Can required approvals be obtained from other agencies?

- Is the technology available?
- Is a remedy administratively feasible (approvals, permits, fees)?

9.3.5 Total Cost

Total costs include the capital costs, indirect costs, and annual operation and monitoring costs. Capital costs involve the actual cost to conduct the remedial work including land rights, material costs, and equipment costs. Indirect costs include engineer design costs, permit costs, and costs to cover unforseen contingencies. Annual operation and maintenance costs are the costs to annually monitor a site until closure, the costs associated with operating a long-term remediation system (i.e., electricity), and the labor costs involved in the above activities. Cost effectiveness refers to the relative cost to implement a remedy that will meet the risk reduction goals of the project. The following questions were used to provide a cost comparison for each alternative:

- What are the total costs involved with this alternative?
- Does the alternative meet the risk reduction goals for the project and how cost effectively does it meet these goals?

The total cost for each of the remedial alternatives is summarized in Tables 9-1 through 9-8. Appendix H contains the detailed cost spreadsheets for each of the remedial alternatives.

9.4 Community and Regulatory Acceptance

The regulatory/community acceptance criteria are not detailed in this FS Report. However, this RI/FS project for the Lower Fox River and Green Bay is being conducted under direct supervision by Wisconsin Department of Natural Resources and U.S. EPA Region 5. Both agencies have been involved with the data collection and analysis efforts, and development of the remedial alternatives and expectations presented in this FS report. Both the state and federal agencies support the evaluation of alternatives and action levels presented in this FS report. As noted on Figure 9-1, community acceptance of these criteria are assessed through substantial public involvement at work shops, public meetings, and working groups, some of which have been completed, and will be completed through the upcoming public comment period. The public comment period will involve public meetings where comments will be solicited by the WDNR on the contents of the RI, RA, and FS reports. Several trustee groups including NOAA, USFWS, and local tribe communities have also been involved in the review and development of the RI/FS reports prior to public release.

The recently completed pilot projects on the Fox River at Deposit N and SMU 56/57 provide examples of communication with the local communities and residents in the selection and implementation of sediment remediation projects. The experience showed that a strong commitment to ongoing communication and outreach efforts greatly facilitated the public input, coordination, and the design of the projects. The agencies received positive feedback on the use of public meetings, media interviews, fact sheets, brochures, the internet, and other methods of disseminating information. Based on the experience of the pilot projects and with previous RI/FS outreach, local concerns are expected to parallel many of the issues explored in the analysis of the CERCLA evaluation criteria such as protectiveness, effectiveness, implementability, and cost. In addition, the community can be expected to have interest in issues such as disturbance and potential risk to local residents, traffic, and noise.

The PCB mass balance study conducted during Deposit N dredging activities (Water Resources Institute, 2000) demonstrated that short-term risks of downstream PCB transport during dredging could be controlled and minimized to less than 1 percent of the PCB mass removed. This study estimated that 96 percent of the PCB mass removed 17 kg (37 pounds) from the deposit was contained in press cake material (ready for off-site disposal) and that less than 0.01 percent (0.2 grams) of the PCB mass removed was discharged back to the river. The downstream concentrations observed during the dredging activity were comparable to background concentrations observed at other times of the year (summer peaks, high-flow peaks) and from other river activities such as passing ship traffic.

A similar community involvement effort was not conducted for the SMU 56/57 demonstration project (in the community of Aswaubenon) in part because this project was in a predominantly industrial area, not near residential properties. Nevertheless, there were extensive informational efforts for the SMU 56/57 project. Upon project completion, most citizens were supportive of the project. During the 2000 dredging activities, there were numerous tours and informational meetings for the media and local communities. Additionally, it was ensured that transportation of dredge spoils from the dredge location to the local disposal facility did not go through residential areas. Similar to Deposit N, there were no significant disruptions to the local community or activities on the river. These projects were well received by the communities.

9.5 Detailed Analysis of Remedial Alternatives for the Lower Fox River and Green Bay

Tables 9-1 through 9-8 provide the detailed screening of the remedial alternatives for each river reach and bay zone respectively. Each table includes the screening of each alternative retained in Section 7 by the nine primary criteria introduced in this section. The evaluation is performed by contrasting each alternative with the questions identified for each primary criteria, regardless of action level. A comparison of action levels within each alternative and between different alternatives is presented in Section 10. Implementation costs associated with each action level are detailed in Section 7. The important evaluation points projected in the tables are summarized below for each remedial alternative. Since the primary concepts evaluated for each alternative are the same regardless of the reach or zone, the four river reaches and four Green Bay zones are summarized together below.

9.5.1 Alternative A - No Action

This alternative involves no active remedy and long-term monitoring to evaluate potential system recovery over time. A detailed evaluation of this alternative is described in Tables 9-1 through 9-8 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Since no active remediation would be undertaken, the site would remain in its current state, with any changes occurring only through natural processes. The Lower Fox River and Green Bay fate/transport and bioaccumulation models predicted that this alternative will not protect human health or the environment over time (in 30 years). Routine monitoring would be performed to maintain the fish consumption advisories already in place.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Since this alternative includes no remedial actions, the magnitude of residual risks remains the same, with any future changes occurring only through natural processes. This alternative is the least-cost alternative, but provides limited adequacy and reliability in terms of long-term risk controls, source control and reduction of exposure pathways. Costs include institutional controls such as fish consumption advisories that would likely remain in place for over 40 years.

9.5.2 Alternative B - Monitored Natural Recovery and Institutional Controls

This alternative involves no active remedy but does incur the expectation that natural processes will contribute to the recovery of the system. Under this alternative, institutional controls will remain in place until the project objectives are eventually obtained. A long-term monitoring plan will be developed to verify natural recovery of the system. A detailed evaluation of this alternative is described in Tables 9-1 through 9-8 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

According to EPA, natural recovery as a remedy is appropriate at sites where the levels of contamination are relatively low, the area of contamination is large, and natural recovery is proceeding at a high rate. The time trends analysis (RI report, RETEC, 2002a) conducted for the Lower Fox River and Green Bay suggests that PCB levels are declining in surface sediments, but no change is occurring at depth. Mass balance work conducted on the Lower Fox River and Green Bay determined, quantitatively, that PCB transport (including Lake Michigan), settling, resuspension, burial, and volatilization mechanisms were all involved (Raghunathan, De Pinto *et al.*, 1994). Empirical data, recently supplied for the fate and transport models, suggest that PCB-contaminated sediments are being transported within the Lower Fox River and into low-level deposits that are widely distributed in Green Bay. Among other lines of evidence, analysis of bathymetry data generated by the USACE show significant movement of sediments in the navigational channels.

Although empirical data may show a slow decline of PCBs in sediment, water, and fish tissues, this alternative may not provide long-term protection of human health and the environment. The transport and bioaccumulation models for the Lower Fox River and Green Bay predict that No Action will require greater than 30 years to consistently reach protective fish tissue thresholds.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Implementation of an active remedy would likely involve a natural recovery component. If a large PCB mass is removed (i.e., source control of sediments) then natural recovery processes may continue after completion of an active remedy thereby continuing the decline of PCB levels in sediment, surface water, and biota. This recovery would be monitored through implementation of a long-term monitoring plan. Some natural processes may accelerate after removal of sediments (i.e., dredging) such as low areas in the river bottom that would likely fill more rapidly. Thus, residual contaminated sediments would be rapidly buried.

The MNR alternative has the lowest total cost among alternatives, but is not cost effective as a standalone remedy because MNR does not meet most of the RAOs in 30 years. Some of the RAOs (i.e., surface water quality criteria) are not met in 100 years. In addition, MNR does not significantly reduce the volume, toxicity, or mobility of COCs throughout the deposit profile over time.

9.5.3 Alternative C - Dredge and Off-site Disposal

This alternative involves physical removal of sediments from the river or bay and off-site disposal of dewatered sediments to a landfill willing to accept dredged sediments. Sediments will be hydraulically or mechanically dredged, then dewatered and solidified, as necessary, prior to off-site disposal. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Based on evidence from other sites, dredging is capable of reducing overall sediment contaminant concentrations, reducing exposure pathways, and reducing long-term risks to human health and the environment, as shown in several case studies (Appendix B). By definition, dredging can serve as an effective source control measure by removing a significant portion of sediment mass and volume from a system. The Lower Fox River and Green Bay modeling results predicts that protective fish tissue levels can be met in 30 years following remedy completion.

Short-term compliance with ARARs and TBCs is expected. The two pilot demonstration projects conducted at Deposit N and SMU 56/57 in the Lower Fox River successfully met monitoring requirements during dredging including: downstream turbidity and PCB levels, effluent water quality, and air quality at compliance boundaries. No ARARs or TBCs were exceeded in the pilot projects.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Depending upon the action level selected for this alternative, residual risk can be two to twenty times lower than the No Action alternative. Dredging with off-site disposal does not destroy or treat material containing PCBs, therefore, PCB volume and toxicity are not reduced. However, effective containment and isolation in a permitted landfill would effectively reduce the mobility of COCs. Reduced mobility and elimination of an exposure pathway would effectively eliminate aquatic exposure and thus reduce the human and ecological risks associated with the consumption of fish.

Short-term Effectiveness. Potential short-term risks associated with dredging do exist. Some of these risks observed on many sediment remediation projects include: the removal, physical disturbance, and/or alteration of aquatic habitats, possible suspension and escape of sediments containing PCBs, and temporary disturbance of silt curtains. Monitoring activities undertaken at other sediment remediation sites (see Appendix B) indicate that potential short-term risks associated with dredging are possible due to the suspension and escape of sediments containing PCBs during dredging (surface water, sediment trap, and caged fish results). For air monitoring, although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions were found to be relatively small and insignificant relative to human exposure and risk. The maximum PCB air levels detected at the sediment processing site did not exceed 80 percent of the protective 70-year cancer risk level.

Measurements of water quality downstream of dredging operations during both the Deposit N and SMU 56/57 demonstration projects reported turbidity measurements consistently below or equal to background values during dredging operations (however the cutterhead dredge at Deposit N only operated for 10 minutes every hour). Based on monitoring of Deposit N, PCB mass loss via downstream transport during dredging operations was estimated to be less than 1 percent of the total PCB mass removed from the deposits. These measurements were comparable to the daily contribution of PCB mass from upstream sources to the project area. In summary, in-water control measures can effectively prevent adverse downstream transport of COCs during dredging operations.

The PCB mass balance study conducted during Deposit N dredging activities (Water Resources Institute, 2000) demonstrated that short-term risks of downstream PCB transport during dredging could be controlled and minimized to less than 1 percent of the PCB mass removed. This study estimated that 96 percent of the PCB mass removed 17 kg (37 pounds) from the deposit was contained in press cake material (ready for off-site disposal) and that less than 0.01 percent (0.2 grams) of the PCB mass removed was discharged back to the river. The downstream concentrations observed during the dredging activity were comparable to background concentrations observed at other times of the year (summer peaks, high-flow peaks) and from other river activities such as passing ship traffic.

Long-term Effectiveness. Removal of impacted sediments provides the most long-term effectiveness compared to other alternatives. Long-term operation and maintenance would not be required after removal.

Technical Implementability. This would be a relatively large dredging project (up to 8 million cy in the river and 25 million cy in Green Bay), without precedent in Wisconsin, although other similar sized projects are currently planned or proposed throughout the United States. Dredging projects of similar size have been implemented internationally (1 million cy in Minamata Bay, Japan) verifying the feasibility of conducting, managing and coordinating a large remedial action. Dry excavation of sediment could provide a suitable and cost-effective alternative to proposed wet excavation methods (using hydraulic and mechanical techniques) but would likely be limited to shallow areas that are easily accessible by land-based equipment. Site-specific use of dry excavation techniques will be evaluated during the remedial design. Construction of a containment structure for dewatering of the dredge prism may adversely affect nearshore habitats and wetlands when compared to wet excavation techniques.

Unexpected site conditions (i.e., wood debris, hard underlying material, debris, cobbles) may have contributed to the inability to meet design goals during the 1999 SMU 56/57 horizontal auger dredging activities. Equipment difficulties and the presence of large debris significantly slowed the pilot test progress. The auger cutterhead dredge produced a sediment slurry with 4.5 percent solids; much lower than the design specifications, however, in 2000, the dredge slurry averaged 8 percent solids. Debris was encountered during dredging, which hindered progress and production rates.

The two pilot projects on the Lower Fox River successfully demonstrated the implementability of environmental dredging, water treatment, and disposal of PCB-contaminated sediment. Both projects extended past the original time schedule due to late season startups. The work was postponed over the intervening winter months and completed the following year. The projects demonstrated the availability of necessary equipment and contractors to perform and oversee this type of work.

Administrative Implementability. As expressed in some of the public comments (April 1999), local siting of landfills for the disposal of PCB sediments is an extremely important factor that has tremendous impact of the cost and implementability of this alternative. Local governments generally support the use of existing local landfills and siting of new landfills, to the extent practicable, but recognize that siting of new landfills is a lengthy process involving multiple layers of cities, towns, villages, and counties. This FS fully anticipates that an in-state landfill will be identified for this alternative, but recognizes that inherent uncertainties exist with this assumption. Additional disposal sites, such as out-of-state landfills and newly constructed CDFs may be necessary to match capacity and volume needs.

With EPA approval, the State of Wisconsin has created a viable in-state alternative for the disposal of PCB-contaminated sediments from the Lower Fox River and Green Bay. In-state licensed landfills can accept TSCA-level sediments (greater than 50 mg/kg PCBs) with long-term protection from liability. Long-term liability protection is also extended to in-state municipal (i.e., county) landfills that accept PCB-impacted sediments with less than 50 ppm PCBs.

Some of the required permits, fees, and approvals required to administratively implement a sediment removal and dewatering operation include: dredging contract fees and bonds (NR 346 WAC), a WDNR permit or authorization from the Legislature to remove material from navigable waters, submittal of a Remedial Action Plan and design document for acquisition of a state permit, and proper manifests and placards for transporting PCB wastes. Construction of an industrial wastewater facility may also be necessary.

Under NR 346 WAC (Dredging Contract Fees), a contract fee of $1 is charged for the removal of material from natural lakes. The contractor removing sediments must have a performance bond which would be used to correct any undesirable environmental conditions caused by improper removal of material.

Under NR 108 WAC (Plans and Specifications), construction of an industrial wastewater facility or an industrial pretreatment facility requires approval of final plans and specifications for the facility by the WDNR. Final plans and specifications must be submitted a minimum of 90 days prior to commencement of construction. A 30-day supply of chemicals is required on site to insure against ineffective treatment, shortages, and delays. Design requirements are established on a case-by-case basis, with incorporation of containment and isolation features necessary to protect water resources. The site could be placed in a floodplain, but still designed to protect resources. Design requirements (Chapters NR 500 to 520 WAC) often include a multi-foot clay liner, leachate collection system, intermediate cover and drainage systems, and a final cover system. Handling areas will be lined and covered.

Under NR 157 WAC criteria (Management of PCBs), transporters of PCB wastes must be licensed for transport of hazardous wastes. PCB wastes must be contained to prevent leakage/spillage, and the transporter is responsible for cleanup of all spillage of PCB wastes. Presence of a spill containment program is required for handling of PCB-containing materials. Under 40 CFR Part 761 (Disposal of PCB Remediation Waste), PCB wastes may require management and transport under a Uniform Hazardous Waste Manifest. Development of a new disposal facility, or expansion of an existing one, is subject to the Wisconsin landfill siting process (Chapter 289 Statutes and Chapters 500 to 520 WAC). Wisconsin's landfill siting process includes the following elements: initial site inspection and report, feasibility report, plan of operation, construction inspections, construction documentation and initial licensure, site closure documentation, and demonstration of financial responsibility and long-term care. Under the Wisconsin State Statutes Chapter 289 (Landfill Siting and Approval Process), local approval may be required prior to siting of a new facility (if petitioned, WDNR may waive requirements).

Under NR 200 WAC criteria (WPDES), effluent water resulting from the dewatering of the dredged sediments will be treated by filtration and flocculation for solids removal. Carbon adsorption may be required in addition to solids removal in order to meet WPDES effluent criteria. Application to discharge pollutants must be on file with the WDNR a minimum 180 days prior to discharge commencement date.

Under Wisconsin Statutes Chapter 30 (Permit in Navigable Waters), a permit is required from the WDNR or authorization from the legislature prior to removing material from navigable waters.

Under NR 322 WAC criteria (Sediment Control During Construction Activities), erosion control measures must be implemented. Silt curtains must be utilized around the perimeter of the work zone to minimize the downstream migration of suspended particles.

For two of the river reaches, Little Rapids to De Pere and the De Pere to Green Bay, one of the proposed alternatives is to hydraulically dredge up to 5,700,000 cy and pump the material through a dedicated pipeline that is approximately 18 miles in length, to a newly constructed receiving landfill. The concept of directly pumping PCB-containing sediments through an urban, residential area for several years to an upland landfill may have several hurdles to overcome including land use, traffic constrictions, community acceptance, and spill controls. However, this alternative is feasible but would be difficult to implement without community support. Construction of another long pipeline has been successfully implemented in Dallas, Texas. This 25-mile pipeline pumped dredge slurry over a year from White Rock Lake through city neighborhoods to a former gravel pit disposal site with two booster pumps (Sosnin, 1998).

The total cost to implement the Dredge and Off-site Disposal alternative is generally more expensive than either the Capping or On-site Disposal alternatives. It is also less cost-effective at meeting risk reduction goals than Capping or On-site

Disposal alternatives for action levels at and below 1,000 ppb (which meet most of the goals in 30 years).

As summarized in the *Sediment Technologies Memorandum* (Appendix B), dredging costs ranged from $280 to $525 per cubic yard for planning, dredging, dewatering, monitoring, and disposal costs for the two demonstration projects.

9.5.4 Alternative D - Dredge and CDF Disposal

This alternative involves physical removal of sediments and long-term disposal of sediments to a newly constructed confined disposal facility (CDF). Sediments will be hydraulically dredged and pumped directly to the CDF or mechanically dredged and placed in the CDF for passive dewatering, then capped. The CDF would be constructed on site as a nearshore or in-water facility dedicated to long-term confinement of sediments. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each of the reaches and zones using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Dredging with direct placement to a CDF would effectively isolate the contaminant mass and therefore provide long-term protection of human health and the environment. Previous USACE and regional studies have shown that CDFs can eliminate the exposure pathways involving ingestion or direct contact with sediment, and subsequent bioaccumulation up the food chain, as long as the CDF containment structure remains intact. Based on monitoring results of other CDFs constructed around the country (see Appendix B), a well-designed CDF structure can effectively isolate COCs and comply with project ARARs. The Lower Fox River and Green Bay modeling results predict that protective fish tissue levels can be met in 30 years following remedy completion.

Short-term compliance with ARARs and TBCs is expected. The two pilot demonstration projects conducted at Deposit N and SMU 56/57 in the Lower Fox River successfully met monitoring requirements during dredging including: downstream turbidity and PCB levels, effluent water quality, and air quality at compliance boundaries. Long-term compliance with ARARs and TBCs related to siting a new CDF is expected prior to construction of new CDF. Monitoring conducted around existing CDFs in Arrowhead Park, Bayport, and Kidney Island show that chemical-specific ARARs and TBCs can be met with effective containment structures.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Residual risks are generally two to twenty times lower than the No Action alternative. However, the removal of sediments during dredging and construction of a CDF may result in relatively long-term changes to the substrate characteristics, and thus the habitat value of the site. In-water placement of a CDF will result in acreage loss of shallow subtidal habitat areas.

Dredging to a CDF does not destroy or treat material containing PCBs, therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway. Short-term environmental risks and controls are similar to those identified for Alternative C.

Construction operations occurring within the river would have a temporary effect on commercial and recreational boating. However, as noted during construction at Deposit N and at SMU 56/57, the physical construction sites themselves drew tourists to the sites. Thus, a net benefit can also be achieved.

Technologies utilized for dredging and on-site disposal are not expected to be different than those identified in Alternative C. In-water CDFs have been successfully constructed through the United States (see Appendix B) and the ability to construct a containment berm and surface cap is well established. No operational difficulties or limited availability is expected that would affect the technical feasibility of this alternative. Segregation of TSCA level sediment would be necessary prior to disposal in a CDF. Administrative implementability would depend on community acceptance of nearshore or in-water disposal of the dredged materials and habitat loss.

9.5.5 Alternative E - Dredge and *Ex-situ* Thermal Treatment

This alternative involves physical removal of sediments and irreversible thermal treatment of sediment coupled with destruction of resulting air emissions. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each reach and zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Dredging with treatment should reduce the bioavailability of PCBs in sediments by removing and eliminating the source of toxicity. Protection of human health and the environment is dependent on the project design and successful implementation of the dredging project (discussed above). Regarding compliance with ARARs, thermal treatment is capable of meeting the air quality ARARs for

PCB air emissions, according to unit specifications and implementation on other projects (see Waukegan Harbor in Appendix B).

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Thermally-treated sediments will achieve long-term effectiveness and permanence. This alternative is the only remedial option that destroys material containing PCBs, therefore, it is the only alternative that reduces the toxicity, volume, and mobility of COCs. This alternative may be costly, but permanently eliminates the risks posed by contaminated sediments. However, thermal treatment by vitrification is not widely used in the United States. This technology also requires significant capital investment.

Under NR 400 through 499 WAC criteria(Air Pollution Control), a construction permit is required for the construction/relocation of a thermal treatment unit. A general operation permit is required prior to the operation of a thermal treatment unit, and an annual emission fee is required if total annual emissions of all air contaminants are less than 5 tons.

The total cost to implement the Dredge and Treat alternative is more expensive than other alternatives with active remedies. This alternative is also less cost effective at meeting risk reduction goals at most action levels. As the action level becomes lower, this alternative becomes less cost effective.

9.5.6 Alternative F - Cap to the Maximum Extent Possible

This alternative involves physical isolation and immobilization of sediments from the water column and biota. This isolation is achieved by placement of an armored sand cap over surface sediments creating *in-situ* containment. This alternative is defined as *in-situ* capping to the maximum extent possible because capping is not practical or implementable in some areas (i.e., navigational channels with frequent dredging needs or minimum water depths to prevent disturbance). A capping alternative was not developed for the Green Bay zones because of the large areal extent of impacted sediments requiring capping and the lack of sufficient local capping material. A detailed evaluation of this alternative is described in Tables 9-1 through 9-4 for each reach and zones using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Previous USACE and other site-specific studies have shown that sand cap containment and armoring can effectively reduce the bioavailability and bioaccumulation of PCBs to aquatic organisms by blocking the transport of PCBs from surface sediments into the overlying water column (see Appendix D).

Containment can provide long-term protection of human health and the environment as long as the system remains intact. This requirement includes preservation and maintenance of the 17 locks and 12 dams located along the Lower Fox River. Monitoring of the cap structure will be required (e.g., sediment cores, caged biota) to ensure containment and structural integrity. The Lower Fox River and Green Bay modeling results predict that protective fish tissue levels can be achieved in 30 years following remedy completion.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Capping is moderately cost-effective when compared to dredging alternatives, but requires long-term deed restrictions, site access restrictions, and long-term monitoring to ensure cap integrity. There is a long-term liability associated with *in-situ* containment of impacted sediments, however, if a conventional cap is placed with the intent of enhanced natural recovery instead of containment, then long-term reduction of contaminant volume and toxicity may be enhanced. Although capping does not reduce or actively treat PCB-contaminated material, it can effectively reduce the mobility of PCBs in a sediment deposit.

In-situ capping does not destroy or treat material containing PCBs, therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway.

Use of proper engineering controls, project planning and design, and contingency plans should mitigate the potential short-term risks associated with resuspended sediment. It is expected that all ARARs and TBCs associated with the implementation of the remedy would be achievable. Environmental impacts and risk to workers during construction and implementation are expected to be low due to the limited disturbance of the impacted material. Potential downstream transport of suspended solids or COCs during placement will be lower for this alternative compared to dredging options. Placement of a cap is technically and administratively implementable, however, physical limitations of the site will limit the practical extent of cap placement. Cap placement in a federally-authorized navigational channel would require special approval by an act of Congress and would be administratively difficult. For the purposes of this FS, navigational channels will be dredged and not capped. The Capping alternative is presented in combination with other dredging and MNR alternatives for all reaches because physical site restrictions prevent cap placement everywhere. Although this alternative is administratively feasible, the large quantity of material required for cap placement will require coordination and acceptance by the community and local industries for land acquisition needed for staging areas.

Cap placement will result in long-term site access and deed restrictions to ensure no disturbances of the cap by passing vessels, ice scour, or other aquatic activities. Long-term maintenance of a sand cap may also potentially impact future commerce or recreational use of the river.

Long-term effectiveness of a cap could be compromised by large-scale flood events, ice scour, vessel draft, or dam removal or failure. These issues can be mitigated by periodic addition of new capping material, armoring the cap with coarser material to minimize future scour potential, or removing the cap entirely and dredging the area. Long-term effectiveness could also be compromised by PCB migration through the cap via groundwater advective processes, but potential groundwater migration would be considered during the design phase. In summary, capping would be less protective as a long-term solution when compared to sediment removal.

The total cost to implement the Capping alternative is generally similar to other remedies for relatively small volumes and considerably less expensive than other remedies for large removal volumes. Capping is generally more cost effective than dredging and similar to on-site disposal alternatives for meeting risk reduction goals. However, as stated above, long-term maintenance and monitoring of a cap will be required.

9.5.7 Alternative G - Dredge to CAD Site

This alternative involves removal of contaminated sediment and placement of material in a confined aquatic disposal site (considered for Green Bay only). This remedy includes mechanical or slurry placement of dredged material in an excavation and covering the material with a sand cap to create a containment cell in an underwater environment. A detailed evaluation of this alternative is described in Tables 9-5 through 9-7 for Green Bay zones 2, 3A and 3B.

Threshold Criteria (Protection and Compliance)

Previous USACE studies and dredge disposal monitoring programs (see Appendix B) have shown that sand cap containment in a CAD site, with natural confinement on the sides and bottom of the excavation, can effectively reduce the bioavailability and bioaccumulation of PCBs to aquatic organisms by blocking the transport of PCBs from surface sediments into the overlying water column. Containment can provide long-term protection of human health and the environment as long as the system remains intact. Monitoring of the CAD structure will be required (e.g., sediment cores) to ensure containment and structural integrity. The Lower Fox River and Green Bay modeling results predict that protective fish tissue thresholds can be achieved in 30 years following remedy completion.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Construction of a CAD site is moderately cost effective when compared to dredging alternatives but requires long-term deed restrictions, site access restrictions, and long-term monitoring to ensure cap integrity. There is a long-term liability associated with in-water containment of contaminated sediments.

Dredging to a CAD site does not destroy or treat material containing PCBs; therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway. Construction of a CAD site and placement of impacted sediments in the disposal site is implementable and has been constructed at numerous sites around the country, many in the New York-Boston area. The same equipment used for dredging can be used to construct the CAD site. Under Wisconsin Statutes Chapter 30 (Permit in Navigable Waters), a permit must be issued by the WDNR or Legislature prior to placing deposits in navigable waters. Implementability is dependent on the Wisconsin Legislature passing a lakebed grant for the use of a CAD site as a disposal site for dredged material.

The total cost to implement the Dredge to CAD Site alternative in Green Bay is generally similar to other active remedies with similar volumes. The total cost to construct a CAD site and transport dredged material to the CAD site is approximately 17 percent less than the cost to construct a freestanding confined disposal facility.

9.6 Summary of Detailed Analysis

The detailed analysis provided in this section provides the basis for the decision-making tools presented in the comparative analysis in Section 10. Each alternative was evaluated against the two threshold and five balancing criteria in detail. Included in this evaluation was the identification and compliance measures for ARARs and TBCs that were chemical, action, and location specific for process options that make up each remedial alternative. Each detailed evaluation was conducted independently and emphasized differences, rather than similarities, that exist between the remedial alternatives within a river reach. These differences will be used in the comparative analysis in Section 10 to provide alternative-specific advantages and disadvantages when comparing alternatives within a river reach.

9.7 Section 9 Figure and Tables

The figure and tables for Section 9 follow page 9-34 and include:

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Figure 9-1 Criteria for Detailed Analyses of Alternatives

Overall Protection of Human Health and the Environment

- How Alternative Provides Human Health and Environmental Protection

Compliance with ARARs

- Compliance and Chemical-specific ARARs
- Compliance with Action-specific ARARs
- Compliance with Location-specific ARARs
- Compliance with Other Criteria, Advisories, and Guidelines

Long-term Effectiveness and Performance

- Magnitude of Residual Risk
- Adequacy and Reliability of Controls

Reduction of Toxicity, Mobility, and Volume through Treatment

- Treatment Process Used and Materials Treated
- Amount of Hazardous Materials Destroyed or Treated
- Degree of Expected Reductions in Toxicity, Mobility, and Volume
- Degree to Which Treatment is Irreversible
- Type and Quantity of Residuals Remaining after Treatment

Short-term Effectiveness

- Protection of Community During Remedial Actions
- Protection of Workers During Remedial Actions
- Environmental Impacts
- Time Until Remedial Action Objectives are Achieved

Implementability

- Ability to Construct and Operate the Technology
- Reliability of the Technology
- Ease of Undertaking Additional Remedial Actions, if Necessary
- Ability to Monitor Effectiveness of Remedy
- Ability to Obtain Approvals from Other Agencies
- Coordination with Other Agencies
- Availability of Off-site Treatment, Storage, and Disposal Services and Capacity
- Availability of Necessary Equipment and specialists
- Availability of Prospective Technologies

Cost

- Capital Costs
- Operating and Maintenance Costs
- Present Worth Cost

State[1] Acceptance

Community[1] Acceptance

Note:

[1] These criteria are assessed in the RI/FS Report and the proposed plan.

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Table 9-1 Detailed Analysis of Alternatives Summary - Little Lake Butte des Morts Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 51 to 84 years to continually meet safe fish consumption levels for recreational anglers. No action will require >100 years to consistently meet safe ecological levels for carp. Surface water quality will not be met in 100 years. PCB loading rates will equal Lake Winnebago inputs in 17 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to no action.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredge and Off-site Disposal	Remedy will require <1 to 57 years to consistently meet safe fish consumption levels after completion of remedy. Remedy will require <1 to 100 years to consistently meet safe ecological levels for carp. Surface water quality for wildlife will be met in 16 to >100 years, other criteria will not be met in 100 years. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. PCB air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and rocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. Winter weather may delay necessary repair or maintenance of cap. Long-term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-1 Detailed Analysis of Alternatives Summary - Little Lake Butte des Morts Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since an active remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	2.1 to 12.4 years estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$116,700,000 for Alternative C1 or $66,200,000 for Alternative C2
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	2.2 to 12.5 years estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$68,000,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	2.1 to 12.4 years estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermally treat the COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$63,600,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	1.7 to 12.5 years are estimated to complete sediment removal. 0.7 to 3.7 years estimated to complete cap placement and 0.7 to 3.3 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. A lake bed permit may be required from the Wisconsin Legislature to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available. Technology and associated goods and services are available to cap sediment deposits.	$90,500,000

Notes:

1 Alternative G was not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-2 Detailed Analysis of Alternatives Summary - Appleton to Little Rapids Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type of Quantity of Treatment Residual	Reductions in Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 51 to 84 years to consistently reach safe fish consumption levels for recreational anglers. No action will require >71 years to consistently meet safe ecological levels for carp. Surface water quality will not be met in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require <1 to 42 years to consistently meet safe fish consumption levels for recreational anglers after completion of remedy. Remedy will require 7 to 89 years to consistently reach safe ecological levels. Surface water quality for wildlife will be met in 19 to >100 years, other criteria will not be met in 100 years. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	As successfully demonstrated during the 1999 Lower Fox River demonstration dredging project at Deposit N, inhalation and disturbance risks to the community can be minimized by: 1) coordination with and involvement of the community; 2) limiting work hours; 3) establishing buffer zones around the work areas; and 4) ambient air monitoring. Risk to workers will be minimized with a site-specific health and safety program.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. thermal treatment treatment residuals include metals/inorganics and ocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-2 Detailed Analysis of Alternatives Summary - Appleton to Little Rapids Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include a remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. As successfully demonstrated during the 1999 Lower Fox River demonstration dredging project at Deposit N, environmental releases can be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runoff; 3) utilizing removal techniques that minimize TSS; and 4) ambient air monitoring. Silt curtains were installed around the dredge areas to minimize downstream transport of COCs in the river, but were deemed unnecessary based on water quality monitoring results. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	0.2 to 1.3 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$20,100,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	0.2 to 1.3 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermal treat the COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$17,100,000

Notes:

1 Alternatives D, F, and G were not retained for this reach.
2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^5 cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.
3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).
4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-3 Detailed Analysis of Alternatives Summary - Little Rapids to De Pere Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 92 to >100 years to consistently meet safe fish consumption levels for recreational anglers. No action will require >100 years to reach safe ecological levels for carp. Surface water quality will not be met in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require 2 to 92 years to consistently meet safe fish consumption levels for recreational anglers after completion of a corrective remedy. Remedy will require <1 to >100 years to consistently reach safe ecological levels for carp. Surface water quality for wildlife will be met in 27 to >100 years, other criteria will not be met in 100 years. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and rocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. Winter weather may delay necessary repair or maintenance of cap. Long-term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-3 Detailed Analysis of Alternatives Summary - Little Rapids to De Pere Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.4 to 10.9 years are estimated for Alternatives C1 and C3, and 0.2 to 1.7 years for Alternative C2 to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$95,100,000 for Alternative C1, $43,900,000 for Alternative C2A, $99,900,000 for Alternative C2B, or $69,100,000 for Alternative C3
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	1.4 to 10.9 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$52,500,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.4 to 10.9 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermal treat the COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediments.	$86,200,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	0.4 to 4.3 years are estimated to complete sediment removal. 1.2 to 4.6 years are estimated to complete cap placement and 1.1 to 4.2 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. A lake bed permit may be required from the Wisconsin Legislature to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available. Technology and associated goods and services are available to cap sediment deposits.	$62,900,000

Notes:

1 Alternative G was not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-4 Detailed Analysis of Alternatives Summary - De Pere to Green Bay Reach (Green Bay Zone 1)

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require >100 years to consistently meet safe fish consumption levels for recreational anglers. No action will require >100 years to consistently reach safe ecological levels for carp. Surface water quality will not be met in 100 years. PCB loading rates into Green Bay will not equal tributary loading rates in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require 7 to >100 years to consistently meet safe fish consumption levels after completion of remedy. Remedy will require 5 to >100 years to consistently reach safe ecological levels for carp. Surface water quality for wildlife will be consistently met in 27 to >100 years. PCB loading rates into Green Bay will consistently equal tributary loading rates in <1 to 36 years following remedy completion. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	As successfully demonstrated during the 2000 Lower Fox River demonstration dredging project at SMU 56/57, inhalation and disturbance risks to the community can be minimized by: 1) coordination with and involvement of the community; 2) limiting work hours; 3) establishing buffer zones around the work areas; and 4) ambient air monitoring. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and large rocks and boulders unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. Winter weather may delay necessary repair or maintenance of cap. Long-term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-4 Detailed Analysis of Alternatives Summary - De Pere to Green Bay Reach (Green Bay Zone 1) (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. As successfully demonstrated during the 2000 SMU 56/57 demonstration dredging project, environmental releases can be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runoff; 3) utilizing removal techniques that minimize TSS; and 4) ambient air monitoring. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	6.1 to 9.3 years are estimated for Alternative C1 and 5.2 to 8.0 years for Alternatives C2 and C3 to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$660,600,000 for Alternative C1, $173,500,000 for Alternative C2A, $491,800,000 for Alternative C2B, or $513,500,000 for Alternative C3
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	6.1 to 9.3 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$505,100,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	5.2 to 8.0 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermal treat the COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$355,100,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	4.2 to 6.3 years are estimated to complete sediment removal. 4.9 to 8.3 years are estimated to complete cap placement and 4.5 to 7.5 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. A lake bed permit may be required from the Wisconsin Legislature to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available. Technology and associated goods and services are available to cap sediment deposits.	$357,100,000

Notes:

1 Alternative G was not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-5 Detailed Analysis of Alternatives Summary - Green Bay Zone 2

Alternative[1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk[2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet safe fish consumption levels for recreational anglers in 100 years (first meet nor consistently meet), regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels for walleye in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will not consistently meet safe fish consumption levels in 100 years after completion of remedy. Remedy will require >100 years to consistently reach safe ecological levels for walleye, regardless of the action taken in the Lower Fox River. Risk reduction is projected for alewife levels (see Section 8). Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-5 Detailed Analysis of Alternatives Summary - Green Bay Zone 2 (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.1 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$507,200,000 (for 5,000 ppb action level)
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	1.1 to 8.2 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$814,100,000
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water to be discharged off site; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) by removing material in an upstream-to-downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. CADs may alter river use availability and aesthetics for riparian owners.	1.1 to 8.2 years are estimated to complete sediment removal (assuming 6 working months per year). 1 to 2 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$697,800,000

Notes:

1 Alternatives E and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-6 Detailed Analysis of Alternatives Summary - Green Bay Zone 3A

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels for walleye in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will not consistently meet safe fish consumption levels in 100 years after completion of remedy. Remedy will require >100 years to reach safe ecological levels for walleye. Some ecological levels for bird deformities associated with alewife consumption (discussed in Section 8) will be met in <30 years following remedy completion. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liner, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long-term disposal. Long-term monitoring and maintenance is included in operation of off-site NR 500 landfill.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-6 Detailed Analysis of Alternatives Summary - Green Bay Zone 3A (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	0.6 day is estimated to complete sediment removal.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Dredging equipment and off-site disposal facilities are commercially available.	$11,000,000 (for 1,000 ppb action level)
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	4.5 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$474,300,000 (for 500 ppb action level)
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment. The construction of a CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns.	4.5 years are estimated to complete sediment removal (assuming 6 working months per year). 2 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$389,100,000 (for 500 ppb action level)

Notes:

1 Alternatives E and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^5 cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level when applicable. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent conting

Table 9-7 Detailed Analysis of Alternatives Summary - Green Bay Zone 3B

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Remedy will require >100 years to consistently meet safe fish consumption levels after completion of remedy, regardless of the action taken on the Lower Fox River. Remedy will require >100 years to reach safe ecological levels for walleye. Some alewife protective levels related to bird deformities will be met in <30 years following completion of a remedy (discussed in Section 8). Surface water quality was not evaluated. Duration of residual risk is dependent upon the selected action level.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepage, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long-term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative D, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-7 Detailed Analysis of Alternatives Summary - Green Bay Zone 3B (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	12 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., NPDES/WPDES) will likely be required for dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$1,155,100,000
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water to be discharged off site; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) by removing material in an upstream-to-downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. CADs may alter river use availability and aesthetics for riparian owners.	12 years are estimated to complete sediment removal (assuming 6 working months per year). 4 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$1,010,900,000

Notes:

1 Alternatives C, E, and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^5 cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-8 Detailed Analysis of Alternatives Summary - Green Bay Zone 4

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken on the Lower Fox River. No action will not meet safe ecological levels in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long-term sediment, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.

Table 9-8 Detailed Analysis of Alternatives Summary - Green Bay Zone 4 (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	Since a remedy is not part of the No Action alternative, there are no environmental impacts associated with the remedy.	No Action alternative does not include a remedy.	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000

Notes:

1 Alternatives C, D, E, F, and G were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^5 cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.