Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

# Appendix K
## Lower Duwamish Waterway Conceptual Monitoring Program

# Final Feasibility Study

## Lower Duwamish Waterway
### Seattle, Washington

**FOR SUBMITTAL TO:**

**The U.S. Environmental Protection Agency**
**Region 10**
Seattle, WA

**The Washington State Department of Ecology**
**Northwest Regional Office**
Bellevue, WA

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## K.1 Introduction

This appendix presents the rationale and conceptual structure for a multi-component Lower Duwamish Waterway (LDW) monitoring program. The conceptual monitoring program serves solely as the basis for estimating the costs of monitoring associated with each remedial alternative (Appendix I). Because it is solely for the limited purpose of costing, the program uses several simplifying assumptions and is not intended to represent the specific scope, timing, and duration of monitoring that will eventually occur in the LDW. The remedy selected by the Agencies will include a monitoring program with a statistical basis for demonstrating compliance with applicable criteria and standards and the success of remedial alternatives, as well as provisions for adjusting the monitoring program to support adaptive management decisions. These details will be determined in the Record of Decision (ROD) and during remedial design.[1]

The monitoring program described herein is sufficiently broad, detailed, and consistent with guidance to fulfill feasibility study (FS)-level scope and cost-estimation objectives. The scope of this appendix is limited to sediment chemistry, porewater chemistry, sediment toxicity, water quality, fish and shellfish tissue chemistry, and physical inspections. Physical maintenance, repairs, and potential adaptive management contingency measures for each remedy component are discussed separately in Sections 9, 10, and 11 of the FS. The temporal elements of this monitoring program (as described in the following sections) include:

- Baseline monitoring
- Construction monitoring
- Post-construction performance monitoring
- Operation and maintenance (O&M) monitoring
- Long-term monitoring.

This appendix sets forth assumptions regarding quantities and frequencies of sampling and reporting that form the basis for cost estimation. Remedial design-level data collection does not fall within the types of monitoring discussed in this appendix. In addition, this appendix does not address monitoring associated with pilot testing technologies, such as adding granular activated carbon, to reduce bioavailability of risk-driver contaminants. This appendix also does not fully address potential adjustments to

[1] This appendix does not consider monitoring associated with nearshore or upland source control. Nearshore source control (e.g., identifying, remediating, or stabilizing erodible banks) is a presumed component of remedial design. The scope of upland source control work, which will involve numerous parties other than those performing the LDW remedy, is beyond the scope of the FS.

the monitoring program needed to assess the long-term effectiveness of such an approach if it were selected as a component of the remedy.

### K.1.1 Performance Objectives for Monitoring

The purpose of monitoring is to collect and analyze repeated observations or measures (chemical, physical, or biological) over time to evaluate changes and trends in site conditions and progress toward achieving the cleanup objectives[2] (EPA 2004). Within this definition, monitoring may have both short-term and long-term objectives and may be linked to technology performance objectives or compliance with applicable or relevant and appropriate requirements (ARARs) and cleanup objectives. The U.S. Environmental Protection Agency (EPA) requires monitoring "to verify that no unacceptable exposures to potential hazards posed by site conditions will occur in the future" and indicates that "the 5-year review should be a review of monitoring data to evaluate whether the remedy continues to provide for adequate, risk-based protection of human health and the environment (40 CFR 300.430 (f)(4)(ii))" (EPA 2004).

The objectives of this conceptual monitoring program, in providing a reasonable basis for the cost estimates in Appendix I, include:

- Establishing baseline conditions to be compared to results of future compliance monitoring.
- Assuring protection of human health and the environment during construction activities and complying with regulatory requirements (construction monitoring).
- Assuring that the remedy remains protective in the long term, e.g., evaluate contaminant migration to surface sediments/surface water via either recontamination from external sources or from break-through of containment technologies.
- Evaluating long-term remedy effectiveness and achievement of cleanup objectives that ensure protection of human health and the environment (long-term monitoring).

Specific parameters/media and associated performance objectives and thresholds are discussed below based on the type of monitoring. The types of monitoring and links to the purpose of either long-term monitoring or technology performance are shown in Table K-1. Upon completion of monitoring events, trends will be evaluated to eventually support management decisions for the site. The definition of project success and the performance metrics for determining success will be developed by EPA and the

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2 Cleanup objective in this FS is used to mean the preliminary remediation goal (PRG) or as close as practicable to the PRG where the PRG is not predicted to be achievable. This FS uses long-term model-predicted concentrations as estimates of "as close as practicable" to PRGs. Additional details regarding cleanup objectives can be found in Section 9.1.2.3.

Washington State Department of Ecology (Ecology) in the ROD, and may be redefined during the 5-year reviews as new data are collected.

### K.1.2 Cost Assumptions

Remedial design and sampling costs are included as a line item under capital costs (Appendix I). Remedial design is applied as a percentage (20%) of the capital costs, and includes predesign sampling and analysis costs. Verification monitoring will be conducted during remedial design; the associated scope and costs are incorporated as a line item in remedial design costs (Appendix I) and are not discussed in this section.

Data collection and frequency assumptions for the five monitoring components described in this appendix are summarized in Table K-2. Table K-2 illustrates the scale of application for each monitoring element. Baseline and long-term monitoring have LDW-wide applications common to all remedial alternatives. They are used to assess the overall condition of the LDW in relation to achievement of the cleanup goals set forth in the ROD. The other three monitoring categories apply at the area- or project-specific level.

For cost estimation, the FS adopts this framework as the cleanup moves from construction to long-term monitoring. It is important to recognize that while the various monitoring types have different objectives and their costs are estimated separately, they are not mutually exclusive. Project-specific and LDW-wide sampling will overlap in certain areas, allowing data to be applied for multiple uses (e.g., to achieve both project-specific and LDW-wide monitoring objectives).

### K.1.3 Consistency with MTCA

The five types of monitoring defined in Table K-2 are consistent with the three types of compliance monitoring requirements described in the Washington State Model Toxics Control Act (MTCA) (Washington Administrative Code [WAC] 173-340-410):

- Protection monitoring confirms that human health and the environment are adequately protected during construction (corresponds to construction monitoring).
- Performance monitoring confirms that remedial actions have achieved the cleanup standards or other performance standards (corresponds to post-construction performance monitoring).
- Confirmational monitoring confirms the long-term effectiveness of a remedial action after the performance standards and/or remediation levels have been achieved. This would include monitoring of disposal, isolation, or containment sites to ensure protection (corresponds to O&M monitoring and long-term monitoring).

Table K-3 cross-references MTCA compliance monitoring requirements with the five types of monitoring identified and described in this appendix.

## K.2 Baseline Monitoring

The objective of baseline monitoring is to establish a site-wide basis for comparing pre- and post-remediation conditions. Baseline monitoring occurs before remediation commences and is distinct from project-specific remedial design sampling and data collection.[3]

The FS sediment dataset includes a large body of data spanning almost 20 years (1991 to 2009) that will inform the scope for baseline monitoring. However, the data are skewed (i.e., unevenly distributed) both geospatially and temporally. The pronounced rates at which sediment from the Green/Duwamish River system accumulates in the LDW (as estimated by the sediment transport model [STM] and discussed in Section 5.1) suggest that conditions may be improved through natural recovery by the time the ROD is issued. Therefore, a new statistically-based LDW-wide baseline dataset that is spatially consistent with future data collection efforts will be required to establish a baseline condition and provide a basis for comparison with post-remediation data. Because the data are collected for trend analysis, no specific threshold criteria are used to evaluate these data.

The sampling design for baseline monitoring should facilitate evaluation of site conditions following completion of cleanups at the early action areas (EAAs) and the aggregate benefits derived from remedial actions over time and relevant spatial scales (i.e., site-wide, potential clamming areas, and beach play areas). A site-wide bathymetric survey and sampling/analysis of sediment, surface water, and fish and shellfish tissue are assumed. In addition, placeholder scope and costs are assumed for additional yet to be defined baseline, upstream, and long-term monitoring surveys (Table K-2 and Appendix I).

## K.3 Construction Monitoring

Construction monitoring during remediation is: area-specific, short term, and used to evaluate whether the project is being constructed in accordance with plans and specifications (i.e., performance of contractor, equipment, and environmental controls). For dredging and capping operations, the objective of construction monitoring is to evaluate water quality near the operations to determine whether the resuspension of

3 Baseline monitoring will occur shortly after the ROD is issued. Remedial design sampling will occur before active remediation in specific project areas and will therefore occur later than and at smaller spatial scales than baseline sampling. Verification monitoring will be concurrent with remedial design sampling.

contaminated sediments and their downgradient movement are being adequately controlled.

Construction monitoring occurs during active portions of a given remedy (i.e., dredging, capping, and enhanced natural recovery [ENR]/*in situ* treatment) and is assumed to be project specific and to consist of:

- Daily field-based water quality monitoring in the immediate vicinity of the active remediation to demonstrate compliance with water quality certification requirements (e.g., physical measures such as turbidity).
- Intermittent collection of downcurrent water column samples for chemical analyses (e.g., polychlorinated biphenyls [PCBs]). The need for chemical analyses will be based on the screening results from the daily field-based water quality monitoring during dredging and sand placement activities. A portion of these samples will be submitted for chemical analyses regardless of the field-based monitoring results.
- Construction quality control to verify achievement of design specifications (e.g., cap area coverage and thickness) intermittently during construction and post-construction. Bathymetric surveys will be used to determine whether target sediments are being removed in dredging operations and whether cap materials are being placed in the design location and at the specified design thickness.

Construction monitoring will be developed on a case-by-case basis for specific areas being remediated and will likely vary (e.g., parameters and frequency) in accordance with the magnitude of contamination. For FS purposes, construction monitoring is assumed to occur during the full duration of each construction season, which in turn, is based on the construction period estimates developed in Section 8 of the FS. FS cost assumptions are outlined in Table K-2.

## K.4 Post-construction Performance Monitoring

The objective of post-construction performance monitoring is to demonstrate whether, after construction, specific cleanup projects comply with project requirements and design specifications (e.g., surface sediment contaminant of concern (COC) concentrations are below the remedial action levels (RALs); average ENR thickness must be at least 6 inches over the intended spatial area). This monitoring focuses on assessing the sediment concentrations of COCs in the actively remediated footprint (i.e., dredging, capping, ENR/*in situ* treatment).[4] Sampling is also assumed for areas peripheral to dredge footprints to support dredge residuals management decisions

[4] Other project requirements such as cap or ENR application thicknesses may also be verified as part of construction monitoring (Section K.3).

(e.g., need for and extent of thin-layer sand placement). Post-construction monitoring varies slightly for different remedial technologies and consists of:

- **Dredging:** Surface sediment sampling and analyses for COCs, grain size, and total organic carbon (TOC) to confirm post-dredge bed conditions; bathymetric surveys to confirm dredge depths.
- **ENR/*In Situ* Treatment and Capping:** Surface sediment sampling and analyses for COCs, grain size, and TOC; ENR/*in situ* treatment/cap thickness verification using a combination of tools, including bathymetric surveys, sediment cores, diver surveys, staking, or settling plates (Anchor 2007).

Post-construction performance monitoring occurs at the end of construction in a specific project area and at the conclusion of each construction season for projects that are only partially completed. A single project-specific bathymetric survey is assumed at the conclusion of construction. FS cost assumptions are outlined in Table K-2.

## K.5 Operation and Maintenance (O&M) Monitoring

The objective of O&M monitoring is to verify that areas requiring management (i.e., dredging, capping, ENR/*in situ* treatment, or monitored natural recovery [MNR]) remain protective. Cap and ENR/*in situ* treatment areas are physically inspected (e.g., diver surveys, bathymetric surveys) to check for evidence of instability and scour. Chemical analyses of surface sediments in all managed areas are used to evaluate recovery status and whether recontamination is occurring. Sediment sampling results will be compared to the RALs and cleanup levels established in the ROD. Additional trends will be evaluated using MNR monitoring data.

The scope of O&M monitoring depends on the remedial action undertaken. The spatial density of samples, frequency, and duration of monitoring are expected to vary (Table K-4). For example, a more intensive program (longer duration and greater sample density) is anticipated for areas undergoing ENR/*in situ* treatment and MNR than for areas remediated by dredging or capping.

Detailed O&M monitoring requirements will be defined during remedial design. For FS cost estimation purposes, the assumed rationale for O&M monitoring is as follows (see Tables K-2 and K-4 for data requirements and collection frequencies):

- **Dredging** – Surface sediment grabs and chemical analyses for COCs are collected to assess whether recontamination is occurring.[5]

[5] Sediment toxicity testing, while not considered a primary test parameter for actively remediated areas, may prove useful in some situations (e.g., to supplement analyses for COCs where recontamination indicates that one or more Sediment Management Standards [SMS] contaminants exceed the sediment quality standards [SQS]).

- **Capping** – Inspections and chemical analyses for COCs in the surface and subsurface sediment and porewater[6] are conducted to assess cap conditions and identify potential concerns with cap surface chemistry, including erosion, settlement/compaction, recontamination, and contaminant flux through the cap. In the event that monitoring indicates recontamination beyond acceptable levels, continued monitoring is needed to verify the extent of recontamination or to establish temporal trends. Physical inspections assess any changes in the cap from erosion or settlement. Potential adaptive management contingency actions based on monitoring and inspection include continued monitoring to establish trends and repair by placement of additional granular material. The FS cost estimate assumes a fixed percentage of the total cap area of each alternative will need supplemental sand placement to ensure cap protectiveness based on monitoring results (Appendix I).

- **ENR/*In Situ* Treatment** – Surface sediment grabs and porewater samples with chemical analyses for COCs are obtained to assess conditions over time. In the event that monitoring indicates recontamination beyond acceptable levels, continued monitoring is needed to verify the extent of recontamination, establish temporal trends, or to inform planning for repairs or contingency actions. The FS cost estimates assume a fixed percentage of the total ENR area of each alternative fails to achieve project-specific goals and reverts to dredging based on monitoring results (Appendix I). The same assumptions are applied to ENR/*in situ* treatment areas. [7]

- **MNR** – MNR requires the most O&M sampling because performance depends solely on natural processes and is thus subject to greater uncertainty compared to dredging, capping, and ENR. Surface sediment grabs with chemical analyses for COCs and toxicity testing are obtained to assess conditions over time. Where monitoring indicates that recovery is progressing adequately toward goals, O&M monitoring continues until recovery is documented and is then discontinued. If monitoring demonstrates an unacceptable rate of recovery, adaptive management contingency actions may be warranted. The FS cost estimates assume a fixed

[6] Recent innovations in porewater sampling techniques, such as solid phase microextraction (SPME) could be used as a cost-effective tool for monitoring porewater chemistry in cap and ENR areas. Porewater data can be used to assess bioavailability or potential breakthrough of contaminants (e.g., polycyclic aromatic hydrocarbons [PAHs]) through cap material (ASTM 2007, Hawthorne 2005). A recent study assessed the use of the SPME method at the Pacific Sound Resources Superfund capping site in Seattle (Reible 2010).

[7] The remedial design plan may select capping technologies to adaptively manage ENR areas instead of dredging, depending on site conditions.

percentage of the total MNR area of each alternative fails to achieve project-specific goals and reverts to dredging based on monitoring results (Appendix I).[8]

## K.6 Long-term Monitoring

Long-term monitoring evaluates sediment, surface water, and tissue quality at the site during and following completion of all remedial actions until EPA and Ecology conclude that remedial action is sufficiently completed and monitoring is no longer required. Fish and shellfish tissue COC concentrations will be used to assess long-term trends in reducing COC concentrations as a function of sediment remediation and source control and in reducing associated human and ecological risks from seafood consumption. Water quality results will be compared to ARARs for surface water.

The scope of a long-term monitoring program is the same as baseline monitoring, and is largely independent of the specific remedial action, although data from other elements of the monitoring program (described in the previous sections) will complement and contribute to the long-term monitoring datasets. Sample numbers and collection frequency will vary by exposure area and media (Tables K-2 and K-5) to:

- Evaluate sediment quality site-wide and in the potential clamming and beach play areas
- Evaluate surface water quality and compliance with surface water quality ARARs
- Evaluate fish and shellfish tissue quality.

Long-term monitoring is expected to inform periodic reviews (typically no less frequently than every 5 years) to allow EPA and Ecology to assess the effectiveness of the remedial actions. Timing of long-term monitoring will need to consider this review cycle. These periodic reviews can inform adaptive management decisions that may be required to achieve the cleanup objectives. In addition, interim monitoring is assumed for longer duration remedial alternatives to determine achievement of cleanup objectives prior to completion of construction, assess chemical trends, and enable risk communication to stakeholders during construction activities.

Table K-2 presents the scope, sample types, number of samples, and sample testing requirements for each of the different monitoring types (surface sediment, surface water, and tissue) assumed for cost purposes in this FS.

8 The remedial design plan may select ENR or capping technologies to adaptively manage MNR areas instead of dredging, depending on site conditions.

## K.6.1 LDW Surface Sediment Quality

Surface sediment sampling approaches for the different exposure areas are described below. In addition, a field study is an assumed component of baseline and long-term monitoring to evaluate the relationship between sediment and clam tissue concentrations of arsenic and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in potential clamming areas. While no specific data quality objectives or experimental design are described herein, a lump sum cost for a field study is included in the cost estimates for the remedial alternatives (see Appendix I).

### K.6.1.1 LDW-Wide Exposure Area

For FS cost estimation purposes, a random stratified design for sample collection is assumed. While a more sophisticated approach may ultimately be developed post-FS (e.g., stratified into reaches, exposure areas) to better manage data skewness and variance, a simple stratified random sampling approach is acceptable for FS purposes for the following reasons:

- Remedial design data collected from contaminated areas designated for cleanup will complement site-wide randomly acquired baseline data and thereby further address data skewness.
- Remediation of the EAAs (Alternative 1) and other hot spots (e.g., those managed by Alternatives 2R and 2R-CAD) is expected to substantially reduce data skewness. Also, project-specific data collected through other types of monitoring (e.g., O&M) will complement site-wide randomly acquired data.

Separating the site into strata acknowledges the skewed distribution of the LDW surface sediment concentration data (Kern 2010). The stratified design assumes two types of data with similar attributes: 1) monitoring data collected from remediated areas at moderate data density, frequency, and variance; and 2) monitoring data collected from unremediated areas at lower data density, with lower variance expected in the range of concentrations observed. Thus, for site-wide baseline and long-term monitoring, 100 surface sediment samples are assumed per sampling event,[9] although the actual population for any given event may be much larger for the reasons mentioned above. Samples will be analyzed for chemical and physical parameters (Table K-2).

[9] One hundred site-wide samples (supplemented with area-specific samples) should have the ability to measure a minimum detectable difference of 25% between the mean of trend data, with a beta = 0.1 and an alpha = 0.05. The 95% upper confidence level on the mean will be used to evaluate future monitoring data.

#### K.6.1.2 Potential Clamming Areas

The potential clamming areas occupy approximately 105 acres of the LDW. For this FS, the potential clamming areas are assumed to be represented by 25 randomly collected samples[10] per event. All sediment samples (collected over a 0- to 45-cm depth for point of compliance) will be analyzed for the parameters shown in Table K-2. This FS assumes collection of discrete or composite samples; various compositing schemes could be considered during design.

Additionally, a field study will be conducted to evaluate the relationship between sediment and clam tissue concentrations of arsenic and cPAHs in the potential clamming areas. Results will be used to evaluate seafood consumption risks for arsenic and cPAHs. The specifics of this field study will be developed subsequent to the FS; costs are currently approximated as a lump sum in Appendix I.

#### K.6.1.3 Beach Play Areas

The eight beach play areas individually range from 1 to 10 acres. For cost estimation purposes, the FS assumes that baseline and long-term monitoring will utilize one composite sample from each beach play area collected from multiple locations to a depth of 45 cm. All composite samples will be analyzed for the parameters shown in Table K-2. An incremental composite sampling scheme may be considered during design as an alternative way of evaluating "average" concentrations over large spatial areas, but this type of remedial design is beyond the scope of this FS.

### K.6.2 LDW Surface Water and Tissue Quality

Surface water sampling is distributed across the LDW at four locations (one upstream and one in each of the three LDW reaches) to assess ambient conditions over time relative to surface water quality ARARs. Samples may be collected as discrete or depth-integrated composite samples; the scope will be determined during remedial design, and will be consistent with baseline sampling. Surface water samples will be analyzed for the chemical parameters shown in Table K-2.

Fish and shellfish tissue sampling are assumed to be of similar scope and magnitude to work conducted in 2005 and 2007 as part of the RI baseline sampling (Windward 2006, 2009). Based on the scope of these previous surveys, the FS assumes about 75 composite tissue samples per event will be collected from various species and tissue types (e.g., whole-body and fillet).[11] Results will be used to assess achievement of cleanup objectives for RAO 1 (human health seafood consumption) and RAO 4 (ecological seafood consumption by river otter). After several years of monitoring (following construction), the frequency of tissue monitoring could be reduced as determined by evaluating trends from the monitoring data (see Table K-5 assumptions).

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[10] Samples may be discrete and/or composite. Assume roughly one sample for every four acres.

[11] The tissue samples will be composite samples collected from fish trawls and crab traps in several subareas for a total of 75 composite samples.

### K.6.3 Incoming Sediment and Surface Water Quality from Upstream

It is anticipated that long-term trends in surface sediment concentrations will eventually reach a point of diminishing reduction, representing a state of relative equilibrium. Beyond this point, additional remediation or source control activities are not expected to further improve sediment contaminant concentrations. At that time, a multi-media sampling effort will be conducted upstream in the Green/Duwamish River to determine the quality of incoming sediment to the LDW. Results will be compared to data collected during a similar baseline sampling event. Another objective of this future data collection effort is to confirm whether further reductions in the LDW are possible. This information is important in determining the closure strategy for the site and overall success of the remedy. Details of the upstream sampling will be determined in collaboration with EPA and Ecology. Assessment of the quality of incoming sediment from lateral sources will also be important for evaluating source control efforts. However, the scope, frequency, and cost for this effort will be determined on a project-specific basis and is not developed in this appendix.

The scope of the upstream sampling is not developed in this appendix, but will likely incorporate methodologies already established by Ecology (Ecology 2008) and surface water sampling events conducted by King County over the past several years (King County 2002). As such, media will include surface water and suspended solids collected over specific time and flow periods. For the purpose of costing the remedial alternatives, a placeholder cost estimate of $600,000 was assumed for this study across Alternatives 2 through 6 (approximately 10 percent of the total long-term monitoring costs) per sampling event and is included in Appendix I.

## K.7 Summary

In summary, a large quantity of data will be collected in the LDW into the future to assess trends, provide risk communication, evaluate remedy construction and technology performance, and evaluate progress toward, or achievement of, cleanup objectives. Table K-6 compiles all of the sampling events described in this appendix, presented by year and remedial alternative. This outline provides sufficient detail to evaluate costs and differences among the alternatives with respect to monitoring requirements.

## K.8 References

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## Table K-1 Purpose of Monitoring and Links to Performance Objectives

### A. Site-wide Monitoring and Associated RAOs

| Media | Remedial Action Objectives | | | | Source Control | Scale of Monitoring | |
|---|---|---|---|---|---|---|---|
| | RAO 1 | RAO 2 | RAO 3 | RAO 4 | | Site-wide and Exposure Area | Area-specific |
| Sediment | X | X | X | X | X | X | X |
| Surface Water | X | | | X | X | X | |
| Tissue | X | | | X | | X | |

Notes:
1. These monitoring program elements, baseline and long-term monitoring, are consistent across all technologies.

### B. Technology Performance Monitoring

| Type of Monitoring/Media | Technology | | | | Scale of Monitoring |
|---|---|---|---|---|---|
| | Dredging | Capping | ENR/ *In Situ* Treatment | MNR | Area-specific |
| *Construction and Post-Construction* | | | | | |
| Sediment | X | X | X | | X |
| Surface Water | X | X | X | | X |
| *O&M Technology Performance* | | | | | |
| Bathymetry | X | X | X | X | X |
| Physical Inspections | | X | X | X | X |
| Sediment | | X | X | X | X |
| Porewater | | X | X | | X |

Notes:
1. The designation ENR/*in situ* treatment indicates that either technology or both may be used.
2. No construction or post-construction monitoring is assumed for MNR, because MNR is passive remediation.

ENR = enhanced natural recovery; MNR = monitored natural recovery; O&M = operation and maintenance; RAO = remedial action objective

## Table K-2 Conceptual LDW Monitoring Program, Used for Cost Estimation

<table>
<tr><th>Monitoring Category[a]</th><th>Parameters</th><th>Sample Collection and Analysis Assumptions</th><th>Sampling Frequency Assumptions and Objectives[b]</th></tr>
<tr><td rowspan="3">Baseline and Long-term[b]</td><td>Bathymetry</td><td>Bank-to-bank and site-wide multi-beam bathymetric surveys (supplemented with land-based survey data for intertidal areas as needed).</td><td>One survey to establish preremedy conditions. Another survey 5 to 10 years into remedy construction as a check on net sedimentation rates and scour areas.</td></tr>
<tr><td>Sediment Chemistry and Toxicity</td><td>LDW-wide: 100 randomly collected surface sediment samples analyzed for the following parameters:<br>• Group A parameters[c] – 100% of samples<br>• Group B parameters[d] – 25% of samples<br>Potential Clamming Areas: 25 randomly collected samples (discrete and/or composites) analyzed for total PCBs, arsenic, cPAHs, and dioxins/furans.<br>Beach Play Areas: Single composite samples from each of 8 beach play areas analyzed for total PCBs, arsenic, cPAHs, and dioxins/furans.</td><td>Sampling occurs over large-scale areas (linked to the exposure areas) to assess compliance with cleanup objectives and ARARs, and to evaluate risk reduction over time.<br>Baseline monitoring: one round of sampling to occur before construction to establish baseline conditions after EAAs have been completed. It also includes verification monitoring in areas expected to be below the SQS. Results can be used to evaluate changes in site conditions after completion of EAAs. One upstream survey event to assess incoming sediment quality.<br>Interim monitoring: no sampling during construction for alternatives that take less than 10 years to implement. For longer duration alternatives (4R, 5R, 6C, and 6R), collect samples every 5 to 10 years during construction for information on chemical trends.<br>• See Table K-5 for sampling frequency.<br>Long-term (after construction) monitoring: sampling occurs at regular intervals after the active portion of the remedy is completed to assess compliance with cleanup objectives and ARARs, and to evaluate trends. Sampling begins 1 to 2 years after construction to allow immediate effects from construction to subside. One upstream survey event after LDW equilibrium is reached to assess incoming sediment quality.<br>• See Table K-5 for sampling frequency.</td></tr>
<tr><td>Surface Water Quality</td><td>Surface water samples collected for analyses of priority pollutant metals, cPAHs, TSS, and PCB congeners at four stations in the LDW</td><td>Baseline monitoring: one round of sampling to occur before construction to establish baseline conditions after EAAs have been completed. One upstream survey event to assess incoming suspended solids and water quality.<br>Interim monitoring: collect surface water samples at regular intervals during construction to assess trends, evaluate source control efforts, and acquire synoptic data with tissue.<br>• See Table K-5 for sampling frequency.<br>Long-term monitoring: same as above for sediment chemistry (4 stations). One upstream survey event after LDW equilibrium is reached to assess incoming suspended solids and water quality.<br>• See Table K-5 for sampling frequency.[b]</td></tr>
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Table K-2 Conceptual LDW Monitoring Program, Used for Cost Estimation (continued)

| Monitoring Category[a] | Parameters | Sample Collection and Analysis Assumptions | Sampling Frequency Assumptions and Objectives[b] |
|---|---|---|---|
| Baseline and Long Term[b] *(continued)* | Tissue[e,f] | Collect 75 fish and shellfish tissue samples (discrete and/or composite) from selected areas consistent with 2007 RI sampling design and scope. Analyze as follows:<br>• PCBs as Aroclors, lipids, solids – 100% of all tissue samples<br>• Arsenic, cPAHs – 100% of clam tissue samples (30% of other tissue type samples)<br>• PCBs as congeners, other chemicals[g] – 33% of samples | <u>Baseline monitoring:</u> one sampling event 1 to 2 years following completion of EAAs to establish preremedy conditions for future comparisons.<br><u>Interim monitoring:</u> collect samples during the active portion of remedy to enable risk communication from dredge operations.<br>• See Table K-5 for sampling frequency.<br><u>Long-term monitoring:</u> collect samples after the active portion of the remedy is completed for all alternatives. The duration of sampling depends on the construction period and the time predicted to achieve long-term model-predicted concentrations.<br>• See Table K-5 for sampling frequency. |
| | Other Surveys | Assume undefined scope for additional misc. surveys yet to be determined during remedial design. These may include benthic infauna surveys, sediment profile imaging camera surveys, sediment cores, or physical assessments. | One event for baseline and one additional event at 5 to 10 years into remedy construction. |
| Construction | Water Quality | Assume four monitoring stations, three for the dredge that operates in deep water and one for the dredge operating in shallow water closer to the banks. Monitor field parameters (e.g., turbidity, pH) at each location:<br>• Downstream mixing zone boundary (far-field) and halfway between mixing zone boundary and operating area (near-field) of deep-water dredge<br>• Upstream reference area<br>• Near-field downstream of the shallow-water dredge.<br>Collect composite water column samples for chemical analyses from each location. Assume 30% of the samples will be analyzed for PCBs, arsenic, TSS, and cPAHs. Screening results may trigger a portion of these samples. Monitoring costs are prorated on a per-day basis (see Appendix I). | Daily during construction operation, assuming two dredging and material placement operations spatially separated so that separate points of compliance are needed. Results used to assess compliance with construction permits.<br>Assume one sampling event for every station each day during each field season for a total number of 352 (88 days × 4 samples/day = 352).<br>One of the stations is an upstream reference area. Samples are used to assess potential impacts associated with dredging, capping, or ENR operations.<br>Field costs calculated on a per-day basis, totaling 88 days per season. Monitoring costs are prorated on a per-day basis (see Appendix I). |

Table K-2 Conceptual LDW Monitoring Program, Used for Cost Estimation (continued)

| Monitoring Category[a] | Parameters | Sample Collection and Analysis Assumptions | Sampling Frequency Assumptions and Objectives[b] |
|---|---|---|---|
| Post-Construction | Sediment Chemistry | The total number of surface sediment samples varies by alternative and is determined by the size of the active remedial footprint (four samples per acre). Immediate post-construction performance testing as follows:<br>• Group A parameters[c] – 100% of samples<br>• Group B parameters[d] – 25% of samples | One sampling event at the end of each construction season (i.e., for partially completed projects) and at the end of each individual construction project to compare to RALs and to determine compliance with design specifications. |
| | Thickness of Placed Material | Verify the thickness of placed material for cap or ENR areas by sediment cores, bathymetric surveys, diver inspection, or settlement plates. Assume 4 samples per acre for sediment cores. Other physical testing parameters could be considered during design. | At the end of construction to confirm material is placed per project specifications. |
| | Bathymetry | One bathymetric survey for each construction area. | At the end of construction to confirm compliance with depth clearance requirements and/or restoration to grade. |
| Operation and Maintenance (O&M) | Sediment Chemistry, Porewater, and Diver Inspection | • Dredge: Two surface samples per acre<br>• Cap: Two surface samples per acre. One sediment core and one porewater sample per acre; inspection by diver at same locations<br>• *ENR/in situ* treatment: Diver inspection and four surface sediment and porewater samples per acre<br>• MNR(10): Four surface samples per acre; periodic physical inspection (by diver) if deemed necessary based on chemistry and grain size results<br>• MNR(20): Same as MNR(10) but longer duration. Additional sampling at Years 15 and 20.<br>Note: Same parameter Groups A and B as for post-construction monitoring (see above) for dredging, capping, ENR/*in situ*, and MNR. | Sampling frequency is different for each remedial technology. Sampling occurs within project-specific remedial footprints to assess technology performance and recontamination potential. For ENR/*in situ* treatment area, porewater sampling will assess bioavailability of contaminants within the treatment area; compare results to RALs and surface water criteria.<br>• See Table K-4 for sampling frequency. |
| | Bathymetry/ Other Physical Surveys | Physical inspection may be conducted by bathymetry, probing, settlement plate, video camera, or other device. Assume:<br>• MNR(10): one physical inspection per 5 acres<br>• MNR(20): same as MNR(10). | Bathymetry and other physical surveys may be employed to assess the extent of potential scour areas. Assessments occur within project-specific remedial footprints. Assume the same frequency as for sediment chemistry sampling. The FS assumes a portion of the footprint will require physical surveys. |

## Table K-2 Conceptual LDW Monitoring Program, Used for Cost Estimation (continued)

Notes:

a. See Appendix I for details regarding frequency and duration of monitoring costs and assumptions. Construction monitoring costs are determined by the number of work seasons. Post-construction and O&M monitoring are area-specific and determined by the size of the remedial footprint. All monitoring assumptions and costs are only for FS purposes and are subject to refinement in the ROD and during remedial design.

b. Timing of sampling events should be designed with consideration of 5-year review cycle to allow data to be used during this evaluation.

c. Group A parameters: total PCBs (as Aroclors), arsenic, cPAHs, all SMS contaminants, and associated conventional parameters (e.g., TOC, grain size, percent solids).

d. Group B parameters: other COCs related to seafood consumption COCs – pesticides, etc. (see Section 3 of the FS for list), plus dioxins/furans, and sediment toxicity tests.

e. A field study is also anticipated to evaluate the relationship between sediment and clam tissue concentrations of arsenic and cPAHs in potential clamming areas. No specific experimental design is assumed for the FS. Field-study costs are approximated as a lump sum value (see Appendix I).

f. The purpose of tissue sampling is to assess cleanup effectiveness relative to RAO 1 cleanup objectives. Tissue sampling monitors concentrations of risk-driver contaminants in tissue, and thus monitors the reduction in human health risks, rather than calculating a prescribed percent reduction. Without a prescribed percent reduction, comparison to baseline is less important than whether future tissue concentrations are in line with changes in sediment concentrations. It is acknowledged that concentrations in tissues will have some year-to-year variability. A subset of the tissue samples will be analyzed as whole-body samples to evaluate RAO 4 cleanup objectives (river otter, ecological seafood consumption risks).

g. Other COCs include, but are not necessarily limited to, dioxins/furans.

ARARs = applicable or relevant and appropriate requirements; COC = contaminant of concern; cPAH = carcinogenic polycyclic aromatic hydrocarbon; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; LDW = Lower Duwamish Waterway; MNR = monitored natural recovery; O&M = operation and maintenance; PCB = polychlorinated biphenyl; RAL = remedial action level; RAO = remedial action objective; RI = remedial investigation; ROD = Record of Decision; SQS = sediment quality standards; TOC = total organic carbon; TSS = total suspended solids.

Table K-3 Comparison of Monitoring Criteria and Terminologies Used in this FS Compared to MTCA

| Monitoring Objective | Type of Monitoring Described in this FS<br>In part, based on EPA contaminated sediment remediation guidance for hazardous wastes sites (EPA 2005) and EPA guidance for monitoring at hazardous waste sites: framework for monitoring plan development and implementation (EPA 2004) | Type of MTCA Compliance Monitoring<br>"shall be required until residual hazardous substances concentrations no longer exceed site cleanup levels established under WAC 173-340 through 173-340-760" [173-340-410][a] |
|---|---|---|
| Establish baseline conditions for future compliance monitoring | Baseline monitoring | n/a |
| Refine the nature and extent of contaminated areas and remedial action boundaries after the FS; confirm recovery processes | Remedial design sampling and verification monitoring[b] | n/a |
| Protect human health and the environment during construction | Construction monitoring (area-specific short-term monitoring during construction) | Protection monitoring |
| Verify that remedial action levels or remediation levels have been achieved before demobilizing from the site | Post-construction performance monitoring (area-specific performance immediately following active remediation) | Performance monitoring |
| Confirm that natural recovery processes are occurring as predicted to achieve cleanup objectives | Operation & maintenance monitoring | Performance monitoring |
| Monitor the stability of a cap area to ensure isolation and containment and of an ENR area to ensure recovery | Operation & maintenance monitoring | Confirmational monitoring |
| Monitor surface sediments over time for potential recontamination | Long-term monitoring | Confirmational monitoring |
| Monitor tissues over time to assess risk reduction | Long-term monitoring | Confirmational monitoring |
| Determine how ongoing sources at or near a site may affect the success of active cleanup and/or natural recovery | Source control evaluation within upland drainage basins – conducted by the Source Control Work Group in parallel to baseline, remedy design, and long-term monitoring; may include other responsible parties | Source control monitoring (but not a component of compliance monitoring) (Ecology 1991) |

Notes:

a. Demonstrating the ability to achieve cleanup standards involves the point of compliance, how long it takes to achieve cleanup levels (time to achieve cleanup objectives or restoration time frame under MTCA), and monitoring to ensure that cleanup standards have been achieved and will continue to be achieved in the future [WAC 173-340-700].

b. Remedial design sampling and verification monitoring are not addressed in this appendix, but are included in the FS as a percentage of capital costs for each remedial alternative (Appendix I).

Shading indicates scope is included in the FS detailed cost estimates for monitoring.

## Table K-4 Conceptual O&M Monitoring Frequency by Remedial Technology

| Remedial Technology | O&M Monitoring for Technology Performance[a] | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample Density (# of samples/acre)[b] | Media | During Construction[c] | Sample Intervals (years post-construction[d]) | | | | | | | | | | | | | | | | | | | |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Dredge | 2 | SS | | | √ | | | √ | | | | | | | | | | | | | | | |
| Cap | 2 | SS | | | √ | | | √ | | | | | √ | | | | | | | | | | |
| | 1 | SC | | | | | | | | | | | | | | | | | | | | | |
| | 1 | PW | | | | | | | | | | | | | | | | | | | | | |
| | n/a | physical | | | | | | | | | | | | | | | | | | | | | |
| ENR or ENR/*in-situ* treatment | 4 | SS | | | √ | | | √ | | | | | √ | | | | | | | | | | |
| | 4 | PW | | | | | | | | | | | | | | | | | | | | | |
| | n/a | physical | | | | | | | | | | | | | | | | | | | | | |
| MNR(10) MNR(20)[e] | 4 | SS | √ | | √ | √ | | √ | | √ | | | √ | | | | | √ | | | | | √ |
| | n/a | physical | √ | | √ | √ | | √ | | √ | | | √ | | | | | √ | | | | | √ |

Notes:

1. The monitoring assumptions provided in this appendix are conceptual and only for FS costing purposes. They are subject to refinement in the ROD and will be finalized during remedial design.

a. See Appendix I for details on O&M monitoring cost estimates for each remedial alternative. Total sample numbers and types vary by remedial technology (as identified in this table) and the areas over which remedial technologies are applied.

b. See Table K-2 for analytical parameters. Surface sediment monitoring may include diver inspections.

c. At a minimum, MNR monitoring begins at the end of the overall remedy construction along with other types of O&M monitoring in active areas (the appendix and costs are based on this assumption). However, it could start earlier in some MNR areas (before the end of construction) if a particular MNR area has minimal potential for recontamination from active remedy construction activities.

d. Timing of sampling events can be adjusted to ensure availability of data for consideration during 5-year project reviews.

e. Sampling for MNR(10) ends at Year 10. Sampling for MNR(20) extends out to Year 20.

n/a = not applicable; MNR = monitored natural recovery; O&M = operation and maintenance; physical = physical inspection surveys, including bathymetric surveys (area-wide) and other physical inspections to ensure limited scour; PW = porewater sample; ROD = Record of Decision; SS = surface sediment grab sample; SC = subsurface sediment core

Table K-5 Conceptual Baseline and Long-term Monitoring Frequency LDW-wide by Alternative

| Remedial Alternative | Media | Baseline | Time from Start of Construction (years) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
| 2R/2R-CAD | SS | SS | | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | T | | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | | | |
| 3C | SS | SS | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | T | | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | | | | |
| 3R | SS | SS | | | | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | T | | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | |
| 4C | SS | SS | | | | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | T | | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | |
| 5C | SS | SS | | | | | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | | T | | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | |
| 4R | SS | SS | | | | | | | | SS | | | PC | | SS | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | T | | | | | T | | T | | | T | | | | | T | | | | | T | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | |
| 6C | SS | SS | | | | | | | | SS | | | | | SS | | | PC | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | T | | | | | T | | | | | T | | T | | | T | | | | | T | | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | | |
| 5R/5R-T | SS | SS | | | | | | | | SS | | | | | SS | | | | PC | | SS | | | | | SS | | | | | SS | | | | | | | | | | | | | | | | |
| | T | T | | | T | | | | | T | | | | | T | | | | | | T | | T | | | T | | | | | T | | | | | | | | | | | | | | | | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | | | | | | | |
| 6R | SS | SS | | | | | | | | SS | | | | | SS | | | | | SS | | | | | | | | | | SS | | | | | | | | | | SS | | | | PC | | SS | |
| | T | T | | | T | | | | | T | | | | | T | | | | | T | | | | | | | | | | T | | | | | | | | | | T | | | | | | T | |
| | SW | SW | | | | | | | | SW | | | | | SW | | | | | SW | | | | | | | | | | SW | | | | | | | | | | SW | | | | | | SW | |

Notes:

(shaded) Indicates approximate construction period in years (see Table K-2 for construction and post-construction sampling)

SS = surface sediment grab sample collection and chemical analysis
T = collection and chemical analysis of 75 fish and shellfish tissue samples (composite) from selected areas consistent with 2007 RI sampling design and scope
SW = collection and chemical analysis of surface water samples
PC = Post-construction sediment sampling prior to site demobilization

1. See Table K-2 for chemical analyses suite, number of samples, and purpose of sampling.
2. The monitoring assumptions provided in this appendix are conceptual and only for feasibility study ( FS) costing purposes. They are subject to refinement in the Record of Decision and will be finalized during remedial design.
3. For the FS, it is assumed that long-term monitoring ends when preliminary remediation goals are met or reach as close as technically practicable to them (i.e., surface sediment concentrations reach long-term, model-predicted concentrations). The last round of sampling is collected prior to the 5-year review.
4. The first sampling event shown on this table (baseline) will also include an upstream sediment/water sample collection event to evaluate incoming sediment quality. The last sampling event shown on this table will also include an upstream sediment/water collection effort.

Table K-6 Summary of All Monitoring Events by Year

Time from Start of Construction (years)

| Remedial Alternative | Preconstruction | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2R/2R-CAD | B/U | D | D | D/R | D/P | | O/M/R | M | R | O/M | | M/R | | | O/M | | R | | | M | | R | |
| 3C | B/U | D | D | D/R/P | | O/M/R | M | R | O/M | | M/R | | | O/M | | R | | | M | | R | | |
| 3R | B/U | D | D | D/R | D | D | D/P | | O/R | M | R | O/M | | M/R | | | O/M | | R | | | M | |
| 4C | B/U | D | D | D/R | D | D | D/P | | O/M/R | M | R | O/M | | M/R | | | O/M | | R | | | | |
| 5C | B/U | D | D | D/R | D | D | D | D/P | | O/M/R | | R | O/M | | R | | | O/M | | R | | | |
| 4R | B/U | D | D | D/R | D | D | D | D | D/R | D | D | D/P | | O/M/R | M | R | O/M | | R/M | | | O/M | |
| 6C | B/U | D | D | D/R | D | D | D | D | D/R | D | D | D | D | D/R | D | D | D/P | | O/M/R | | R | O/M | |
| 5R/5R-T | B/U | D | D | D/R | D | D | D | D | D/R | D | D | D | D | D/R | D | D | D | D/P | | O/M/R | | R | O/M |
| 6R | B/U | D | D | D/R | D | D | D | D | D/R | D | D | D | D | D/R | D | D | D | D | D/R | D | D | D | D |

| Remedial Alternative | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2R/2R-CAD | | M | | R/U | | | | | | | | | | | | | | | | | | | |
| 3C | M | | R/U | | | | | | | | | | | | | | | | | | | | |
| 3R | R | | | M | | R/U | | | | | | | | | | | | | | | | | |
| 4C | R | | | | | R/U | | | | | | | | | | | | | | | | | |
| 5C | | R | | | | | R/U | | | | | | | | | | | | | | | | |
| 4R | R | | | | | R/U | | | | | | | | | | | | | | | | | |
| 6C | R | | | O/M | | R/U | | | | | | | | | | | | | | | | | |
| 5R/5R-T | | R | | | | | R/U | | | | | | | | | | | | | | | | |
| 6R | D | D | D | D | D | D/R | D | D | D | D | D | D | D | D | D | D | D | D | D | D/P | | R/U | |

Notes:

Indicates approximate construction period in years

Type of Monitoring (see Table K-2 for description)

- B = baseline or preconstruction: surface sediment, tissue, surface water, physical
- D = during construction: surface water
- P = Post-construction for each construction area: surface sediment, bathymetry; frequency could be every year for each subarea completed
- O = O&M for active remedial technologies employed (i.e., dredge, cap, ENR/*in situ* treatment) after active remediation has been completed for the alternative: multi-media
- M = MNR O&M (includes years when other O&M is not being conducted): surface sediment
- R = interim and long-term after active remediation has been completed for the alternative: surface sediment, tissue, surface water
- U = upstream multi-media sampling event(s) to assess the quality of incoming sediment, suspended solids, and surface water

1. See Table K-2 for chemical analyses suite, number of samples, and purpose of sampling.
2. The monitoring assumptions provided in this appendix are conceptual and only for FS costing purposes. They are subject to refinement in the Record of Decision and will be finalized during remedial design.

CAD = contained aquatic disposal; O&M = operation and maintenance