# Lower Duwamish Waterway Group

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

# Final Feasibility Study

## Lower Duwamish Waterway

Seattle, Washington

Volume I - Main Text, Tables, and Figures

Sections 11, 12, and 13


PREPARED BY:

AECOM

710 SECOND AVE, SUITE 1000

SEATTLE, WA 98104


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THE WASHINGTON STATE DEPARTMENT OF ECOLOGY
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# 11 MTCA Evaluation of Remedial Alternatives

This section of the feasibility study (FS) evaluates the remedial alternatives[1] under the State of Washington Model Toxics Control Act (MTCA) requirements for conducting an FS. As stated within the Washington Administrative Code (WAC) 173-340-350, the purpose of an FS is to develop and evaluate remedial alternatives that will enable a remedial action to be selected for the site. This purpose is similar to that stated under the Comprehensive Environmental Response, Conservation, and Liability Act (CERCLA) of 1980. The Washington State Department of Ecology (Ecology) either conducts or oversees cleanup actions by liable parties under MTCA, as state law, but may also conduct or oversee such actions under CERCLA. The U.S. Environmental Protection Agency (EPA) either conducts cleanup actions or oversees such actions by responsible parties under CERCLA (with more stringent substantive MTCA requirements as applicable or relevant and appropriate requirements [ARARs]). EPA does not conduct cleanup actions under state law. Both Ecology and EPA are reviewing the FS and EPA will select the remedial alternative for the Lower Duwamish Waterway (LDW) in a Record of Decision (ROD).

The LDW FS is structured using the CERCLA guidance framework for developing, evaluating, and presenting the analysis of remedial alternatives. This approach is appropriate because MTCA and CERCLA are fundamentally similar. This section evaluates information developed and presented elsewhere in the FS, using the specific methodology and criteria set forth in MTCA (WAC 173-340-360). EPA provided limited input into the disproportionate cost analysis (DCA), because it will be relying on the nine criteria analysis required under CERCLA to select a cleanup alternative in the ROD. Ecology co-issued the remedial investigation (RI)/FS Administrative Order on Consent (AOC) and has overseen its implementation with EPA. The FS anticipates that Ecology will work with EPA to select the preferred remedy published in the Proposed Plan and will similarly work with EPA on the ROD. This evaluation is similar to the CERCLA comparative analysis evaluation in Section 10.

## 11.1 MTCA Requirements for Content of the FS

The general content and requirements under MTCA for an FS include:

- Developing cleanup standards applicable to the site. These standards are similar to preliminary remediation goals (PRGs) presented in Section 4.
- Assembling remedial alternatives that protect human health and the environment by eliminating, reducing, or otherwise controlling risks posed through each exposure pathway and migration route identified for the site.

[1] MTCA refers to remedial alternatives as cleanup action alternatives. For consistency with the rest of the FS, the term "remedial alternatives" is retained in this section.

Remedial alternatives were assembled in Section 8. Section 9 presented the predicted outcomes of each remedial alternative.

- Using remediation levels to define when particular remedial alternative components will be used. Remedial action levels (RALs), which are essentially the same as remediation levels, are developed in Section 6.
- Using remedial action components that reuse or recycle, destroy or detoxify, immobilize or solidify hazardous substances, or provide for on-site or off-site disposal in an engineered, lined, and monitored facility or on-site isolation or containment of the hazardous substances with attendant engineering controls, and institutional controls and monitoring. The remedial alternatives incorporate a reasonable array of remedial technologies, which were screened in Section 7.
- Developing a reasonable number and types of alternatives, taking into account the characteristics and complexity of the LDW, including current site conditions and physical constraints. Eleven remedial alternatives were developed in Section 8 using 5 sets of RALs (Alternatives 2 through 6), two sets of technology options (combined technology [“C”] and removal emphasis [“R”]), two disposal options (upland disposal [default disposal option for all alternatives] and contained aquatic disposal [CAD] for Alternative 2R-CAD), and one treatment option (soil washing). The complete set of alternatives, including the no further action alternative, is: 1, 2R, 2R-CAD, 3C, 3R, 4C, 4R, 5C, 5R, 5R-Treatment, 6C, and 6R.
- Evaluating the residual threats that would accompany each remedial alternative to determine if alternatives are protective of human health and the environment. The risk-based outcomes and restoration time frames for each alternative are described in Section 9 and are incorporated into Sections 11.4 and 11.5.
- Using a standard point of compliance for alternatives unless it is not practicable, and using, as appropriate, alternatives with conditional points of compliance. Points of compliance for each alternative were discussed in Section 8 and are summarized in Section 11.3.
- Evaluating alternatives, using the “minimum requirements,” which include threshold requirements, other requirements, additional minimum requirements, and identifying those alternatives, e.g., Alternative 6R, for which costs are disproportionate as shown by the DCA. Sections 11.2 through 11.5 present the MTCA evaluation of the remedial alternatives.

## 11.2 MTCA Minimum Requirements for Remedial Actions

Under MTCA, remedial alternatives are evaluated within the framework of minimum requirements, including threshold requirements, other requirements, and additional minimum requirements, as specified in WAC 173-340-360. Table 11-1 provides a schematic of the MTCA remedy selection process, which illustrates the process of screening the remedial alternatives against minimum requirements, and then comparing them using a DCA. Table 11-2 cross-references the minimum requirements to sections of the FS where relevant information and analyses are presented.

### 11.2.1 Threshold Requirements

WAC 173-340-360(2)(a) lists four threshold requirements for remedial actions. All remedial actions must:

- Protect human health and the environment.
- Comply with cleanup standards.
- Comply with applicable state and federal laws.
- Provide for compliance monitoring.

An evaluation of the remedial alternatives against these threshold requirements is presented in Section 11.3.

### 11.2.2 Other Requirements

Under MTCA, alternatives that achieve the threshold requirements must also achieve the following “other requirements” (WAC 173-340-360(2)(b)):

- Provide for a reasonable restoration time frame.
- Use permanent solutions to the maximum extent practicable, as determined by the DCA.
- Consider public concerns.

Each of these other requirements is described below.

#### 11.2.2.1 Reasonable Restoration Time Frame

MTCA requires that remedial alternatives provide for a reasonable restoration time frame (i.e., determining reasonable time to achieve cleanup standards based upon requirements and procedures in WAC 173-340-360(4)). MTCA provides no specific reasonable restoration time requirement but allows for a comparison of restoration time frames among the remedial alternatives; these are discussed in the context of the remedial alternatives in Section 11.4. The Washington State Sediment Management Standards (SMS) require an evaluation of the practicability of achieving a 10-year restoration time frame after construction, but allows restoration time frames to exceed 10 years where it is not practicable to achieve the cleanup standards within 10 years.

#### 11.2.2.2 Disproportionate Cost Analysis (DCA)

MTCA specifies that, when selecting a remedial alternative, preference shall be given to actions that are permanent solutions to the maximum extent practicable. Multiple actions to achieve cleanup standards are possible for the LDW. Identifying an alternative that is permanent to the maximum extent practicable requires weighing the costs and benefits of each. MTCA uses a DCA (WAC 173-340-360(3)(e)) as the tool for comparing each remedial alternative's incremental environmental benefits with its incremental costs. The following criteria, which are further defined under WAC 173-340-360(3)(f), are used to evaluate and compare remedial alternatives when conducting a MTCA DCA:

- Protectiveness
- Permanence
- Long-term effectiveness
- Short-term risk management
- Implementability
- Consideration of public concerns
- Cost.

This DCA is not an ARAR under CERCLA; it is a procedure required by MTCA to evaluate and potentially screen out alternatives for which the implementation costs are disproportionate to the benefits achieved. According to WAC 173-340-360(3)(e)(i), costs are considered disproportionate to benefits when the incremental costs of the alternative exceed the incremental benefits achieved by the alternative compared to that achieved by other lower-cost alternatives.

#### 11.2.2.3 Consider Public Concerns

MTCA requires that public concerns solicited throughout the cleanup process pursuant to WAC 173-340-660 be considered. Consideration of community acceptance (including concerns of individuals, community groups, local governments, tribes, and federal and state agencies) has been a consistent part of the process of developing the FS, which includes review cycles, periods of public comment, community technical advisory groups, and community meetings. Consideration of public concerns to date has been qualitatively incorporated into the DCA in this FS. EPA and Ecology invited the public to review and comment on the Draft Final FS for the LDW, which was published October 15, 2010. More than 300 letters were received from individuals, businesses, interest groups, tribes, and government agencies. Key topics from these letters are summarized in Section 9.1.3. In addition, the ROD will include a formal response to public comments on the Proposed Plan. In contrast, while EPA often receives public comment on CERCLA remedial actions before EPA issues a Proposed Plan, the Proposed Plan is the only document for which EPA is required by CERCLA to solicit public comment (other than a consent decree to implement a remedial action).

### 11.2.3 Additional Minimum Requirements

Additional minimum requirements are described in MTCA as relevant for comparing and evaluating alternatives. These are described below and listed in Table 11-2.

#### 11.2.3.1 Institutional Controls

Institutional controls are required by MTCA for all sites where hazardous substances remain at concentrations that exceed cleanup levels for unrestricted use (WAC 173-340-440(4)). All of the alternatives presented in Section 8 rely in part on institutional controls to protect human health, because none of the alternatives can achieve the total polychlorinated biphenyls (PCB) and dioxin/furan PRGs that are set at natural background for the human seafood consumption scenario. Institutional controls may also be required to protect certain elements of the remedial alternatives (e.g., engineered caps) to protect both human health and the environment.

MTCA (WAC 173-340-360(2)(e) and 173-340-440) requires that remedial alternatives that include institutional controls satisfy the following provisions:

- Remedial alternatives shall meet each of the minimum requirements in WAC 173-340-360 (2).
- The institutional controls should demonstrably reduce risks to ensure a protective remedy. This demonstration should be based on a quantitative scientific analysis where appropriate.
- Remedial alternatives shall not rely primarily on institutional controls and monitoring where it is technically possible to implement a more permanent remedial alternative for all or a portion of the site.
- Compliance with institutional controls requirements is part of periodic reviews specified in WAC 173-340-420.

Sections 11.2 through 11.5 address the first provision and evaluate the alternatives against the minimum requirements. Section 7 of this FS provides a detailed discussion of institutional controls, including a discussion of how they would reduce risks. The third provision is addressed within the DCA presented in Section 11.5. The fourth provision is included in compliance monitoring, as described in Appendix K.

#### 11.2.3.2 Releases and Migration

Remedial alternatives shall prevent or minimize present and future releases and migration of hazardous substances in the environment (WAC 173-340-360(2)(f)). Pertinent factors that are considered for this evaluation include:

- Releases during implementation (e.g., during dredging or contained aquatic disposal)
- Releases associated with treatment residuals
- Potential future releases from scour in passive remediation and enhanced natural recovery (ENR) areas
- Potential future releases from failure of engineered containment remedies (e.g., caps)
- Control of ongoing sources of sediment contamination, including media that have been contaminated from historical releases or practices.

Construction best management practices and proper residuals management are designed into the engineering and construction management of the remedial alternatives to limit resuspension of contaminated sediment and recontamination of adjacent areas. Although minimized to the maximum extent practicable, resuspension from dredging still figures significantly in the short-term risk impacts. Capping with appropriately engineered armoring is considered in locations with the potential for significant erosion from high flows or vessel traffic. Capping limits the potential for future exposure of buried contaminated sediment. Application of ENR/*in situ* treatment[2] and monitored natural recovery (MNR) is limited in areas with potential scour (see Section 8 for details). In addition, a preliminary analysis of migration of hydrophobic organics (e.g., PCBs and polycyclic aromatic hydrocarbons [PAHs]) through caps (Section 7.1.4), shows that these contaminants of concern (COCs) would not migrate through a cap even in areas with low rates of sedimentation (less than 0.5 centimeters per year [cm/year]), and that caps can be engineered to retard breakthrough of COCs for 100 years or more in the absence of sedimentation (see Appendix C, Part 8). Maintenance and monitoring of the remedial actions will continue in an effort to minimize future releases.

[2] For remedial alternatives with combined technologies, ENR/*in situ* treatment areas will be remediated with a thin-layer sand placement (ENR) or a thin-layer sand placement with carbon amendments (*in situ* treatment). The decision of whether to use ENR with or without *in situ* treatment would be made during remedial design. The FS assumes that 50% of the area designated for ENR would warrant the use of *in situ* treatment.

Source control and potential ongoing releases from sources are key considerations in all alternatives (see Section 2.4 and Section 8.4.1). Sediment remedies must be integrated with other actions to control sources of contamination to the sediments and water. Numerous actions are underway to clean up facilities near the LDW and control sources of contamination to the maximum extent practicable. Control of sources that caused sediment contamination or have the potential to cause recontamination is a critical element of all alternatives. Actions to control contaminant releases and migration are beyond the scope of this FS, but must be integrated with sediment remedies during the design of remedial actions (Ecology 2004). Generally, the control of sources to the maximum extent practicable is a MTCA expectation wherever attenuation of hazardous substances is part of a cleanup action (WAC 173-340-370(7)(a)).

#### 11.2.3.3 Dilution and Dispersion

Remedial alternatives shall not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measure over the costs of dilution and dispersion grossly exceed the incremental degree of benefits of active remedial measures over the benefits of dilution and dispersion (WAC 173-340-360(2)(g)).

The alternatives presented in this FS do not rely primarily on dilution and dispersion.

#### 11.2.3.4 Remediation Levels

The MTCA term "remediation level (REL)" is essentially synonymous with "remedial action level (RAL)" used in previous sections of this FS. Remedial alternatives that use remediation levels shall meet the following requirements:

- Remedial alternatives shall meet each of the minimum requirements in WAC 173-340-360(2), including a determination that the remedial action is protective of human health and the environment
- Selection of a remedial alternative that uses remediation levels requires a determination that a more permanent remedial alternative is not practicable based on the DCA.

Each alternative uses RALs developed in Section 6 and institutional controls to protect human health and the environment.

## 11.3 Evaluation of Alternatives against Threshold Requirements

This section evaluates each remedial alternative with respect to the threshold requirements set forth in WAC 173-340-360. Table 11-3 summarizes the evaluation of remedial alternatives against each threshold and other requirement. For any alternative, the four threshold criteria must be achieved to be considered viable as a remedial alternative for the LDW and be carried forward in the evaluation. Ultimately, Alternatives 2 through 6 are designed to satisfy the four threshold requirements with critical differences in degree of certainty, reliance on institutional controls, and remediation time frames.

### 11.3.1 Protect Human Health and the Environment

Protection of human health and the environment is measured by each alternative's ability to achieve MTCA cleanup standards, while considering factors such as:

- The comparative permanence derived from removing contamination from the LDW system that would otherwise have to be managed and/or potentially addressed in the future, and
- Short-term impacts to human health and the environment (e.g., benthic community and habitat loss, increased fish and shellfish tissue contaminant concentrations during dredging and resulting increased risk to seafood consumers and river otters, community impacts from traffic, noise, and emissions) that may result from active remediation to achieve greater permanence.

In the LDW, risk reduction is measured by the achievement of the MTCA cleanup standards (Table 11-3). Detailed predicted outcomes expressed as contaminant concentrations and associated risk estimates are provided in Section 9 and Appendix M. Tables 9-2a and 9-3 present predicted human health risk-driver concentrations in surface sediments that are achieved over time by the alternatives. Tables 9-7a, 9-7b, and 9-8 present the predicted human health risks for each remedial alternative. Tables M-5a through M-5d in Appendix M, Part 1 present predicted risks for individual contaminants for the direct contact scenarios.

As indicated in Table 11-3, risk reduction for remedial action objectives (RAOs) 1 through 4 is achieved for Alternatives 2 through 6 using different combinations of active remediation, natural recovery, source control, and institutional controls to reduce exposures. As discussed in Sections 9 and 10, the overall improvement in the quality of the LDW aquatic environment for Alternatives 2 through 6 is predicted by modeling to be similar over the 10- to 30-year time frame with varying degrees of certainty and permanence. Remedy construction can result in related environmental risks (see Table 10-1). For example, dredging activities that remove contaminants from the LDW and therefore provide greater long-term protectiveness and permanence are also associated with relatively higher short-term risk of water quality inputs, elevated concentrations of COCs in fish and shellfish tissue, and potential sediment recontamination, compared to other remedial technologies such as capping, ENR, and MNR. Some short-term risks can be reduced through prudent design practices and best management practices during construction.

Alternatives 2 through 6 pass the threshold criteria of protecting human health and the environment although the alternatives achieve protectiveness by different means. Long-term risks and short-term (i.e., construction-related) risks are further evaluated as part of the DCA in Section 11.5.

As stated elsewhere in the FS, the LDW is a complex and dynamic system. This FS is intended to provide a best estimate of the comparative risks to human health and the environment that would remain after remediation under various alternatives. However, uncertainty is inherent in predictions of future environmental conditions. To attempt to address these uncertainties, a sensitivity analysis was performed using the bed composition model (BCM) to try to bound the range of potential outcomes after remediation. The analysis is presented in Section 9, additional sensitivity results are included in Appendix M, and model uncertainty is further discussed in Section 9.3.5. The potential range of outcomes for the remedial alternatives was produced by varying the BCM parameter input values. In addition, an estimate of the degree of certainty that the remedial alternatives will be successful is incorporated into Metric 3a of the DCA (Table 11-6 and Section 11.5.2.3).

### 11.3.2 Comply with Cleanup Standards

For remedial alternatives to be considered viable, the alternatives must comply with cleanup standards. Cleanup standards in MTCA have three components: cleanup levels, points of compliance, and ARARs. Cleanup standards will be set by EPA and Ecology in the ROD. For this FS, the cleanup levels are the PRGs, which were developed considering both risk-based cleanup levels and ARARs along with practical quantitation limits (PQL) and background concentrations. The point of compliance for sediments throughout the LDW is a 10-cm depth, except in potential clamming and beach play areas when addressing PRGs for direct contact pathways. In those areas, the FS assumes the point of compliance is a 45-cm depth to be protective of direct contact exposures (RAO 2).

The PRGs developed in Section 4 considered MTCA requirements for cleanup levels. MTCA requires that cleanup levels achieve a hazard index of 1 or less and a total excess cancer risk of $1 \times 10^{-5}$ or less. MTCA also requires that the excess cancer risk for each individual hazardous substance must be $1 \times 10^{-6}$ or less. MTCA allows an upward adjustment of the cleanup level to natural background or the PQL, whichever is greater, if the cleanup level is below natural background or the PQL. All PRGs and the basis for each are listed in Tables 4-7 and 4-8.

Table 11-3 summarizes predicted outcomes for the remedial alternatives with respect to the RAOs and PRGs, based on the information presented in Section 9. Most PRGs are predicted to be achieved at the end of construction or within 10 years after construction, depending on the alternative and risk endpoint (e.g., natural background-based PRGs).

None of the alternatives are predicted to achieve the PRGs for RAO 1; however, risk reduction is managed for PCBs and dioxins/furans through a combination of active remediation, natural recovery, and institutional controls (e.g., seafood consumption advisories) to reduce exposures (as discussed in Section 9). To the extent that all practicable remediation cannot achieve PRGs, the alternatives would rely on institutional controls to reduce human exposure to COCs in resident fish and shellfish. Some institutional controls, such as seafood advisories, are not enforceable and therefore have limited reliability.

For RAO 2, all alternatives are predicted to achieve a total direct contact excess cancer risk (from all risk drivers combined) of less than or equal to $1 \times 10^{-5}$ and a hazard index of less than 1. All alternatives are predicted to achieve a direct contact excess cancer risk of less than $1 \times 10^{-6}$ for total PCBs, dioxins/furans, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) (except for Beach 3).

For cPAHs, the PRG for the beach play direct contact scenario (90 micrograms toxic equivalent per kilogram dry weight [µg TEQ/kg dw]) is not predicted to be achieved at some beaches by any remedial alternative. This PRG is based on achieving $1 \times 10^{-6}$ excess cancer risk or less for beach play areas. All of the alternatives are predicted to achieve a risk threshold of $1 \times 10^{-6}$ or less[3] except for Beach 3, which is likely influenced by lateral sources. Alternatives 1 and 2 are predicted to achieve this risk threshold of $1 \times 10^{-6}$ within approximately 25 and 10 years after construction, respectively. Alternatives 3 through 6 are predicted to achieve the $1 \times 10^{-6}$ risk threshold prior to or immediately following construction, except for Beach 3, as discussed above.

For arsenic, none of the alternatives are predicted to achieve the arsenic PRG of 7 milligrams (mg)/kg dw, which is based on natural background; however, concentrations are predicted to be close to the PRG and are predicted to be within the long-term model-predicted concentration range at or before the end of construction for Alternatives 2 through 6.

For RAO 3, Alternatives 2 through 6 are predicted to achieve the SQS within 10 years after construction. Alternative 1 may need more than 10 years of natural recovery to achieve the SQS.

For RAO 4, Alternatives 2 through 6 are predicted to achieve a hazard quotient of less than 1 following construction and Alternative 1 is predicted to achieve a hazard quotient of less than 1 within 5 years following construction.

### 11.3.3 Comply with Applicable State and Federal Laws

This criterion is discussed in Section 9.1.1.2. All remedial alternatives would likely comply with the applicable state and federal laws, except for federal and state water quality criteria and standards for some COCs. (Note that Sections 9 and 10 discuss

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[3] As a result of rounding, predicted cPAH concentrations of up to 134 µg TEQ/kg result in an excess cancer risk estimate of $1 \times 10^{-6}$ or lower.

compliance with MTCA requirements as CERCLA ARARs, whereas this section discusses MTCA requirements in Section 11.3.2, Comply with Cleanup Standards. MTCA requirements are not literally MTCA ARARs.)

### 11.3.4 Provide for Compliance Monitoring

Section 8.2.4 describes the MTCA requirements for protection, performance, and confirmation monitoring. The monitoring program included in Alternatives 2 through 6 allows the progress toward achieving cleanup standards to be assessed on a periodic basis. The conceptual monitoring program as presented in Appendix K complies with the MTCA requirements and Table 8-10 cross-references the MTCA monitoring terms with the CERCLA monitoring terms used in this FS.

### 11.3.5 Threshold Requirements Summary

The remedial alternatives are not predicted to ultimately achieve compliance with some cleanup levels; thus, institutional controls must be included to reduce human exposure to COCs in resident fish and shellfish to the extent all practicable remedial measures cannot achieve them. Some institutional controls, such as seafood advisories, are not enforceable and therefore have limited reliability. The estimated time required to achieve compliance and the degree of certainty in these estimates vary among the alternatives. The extent to which Alternatives 2 through 6 comply with the applicable state and federal laws is discussed above in Section 11.3.3, and all of these alternatives incorporate the compliance monitoring required for evaluating whether cleanup standards are being achieved.[4]

## 11.4 Provide for a Reasonable Restoration Time Frame

WAC 173-340-360(4)(b) presents several "factors" to consider when determining whether a remedial alternative has a reasonable restoration time frame. Relevant factors (i) potential risks posed by the site to human health and the environment; (iii) and (iv) current and potential future use of the site and associated resources affected by the releases; (vi) likely effectiveness of and reliability of institutional controls; (vii) ability to control and monitor migration of hazardous substances; (viii) toxicity of hazardous substances; and (ix) natural recovery are generally evaluated as part of the CERCLA nine criteria analysis. The SMS standards in WAC 173-204-580(3)(a) list similar factors when determining if a remedial alternative has a reasonable "cleanup time frame" (applicable to RAO 3) including "the practicability of achieving the site cleanup standards in less than a 10-year period [after construction]." Natural recovery processes may be used to meet these cleanup standards after remedy completion.

[4] Alternative 1 also includes monitoring outside of the early action areas (EAAs), but it does not include contingency actions outside of the EAAs to ensure cleanup standards are being achieved.

Table 11-3 summarizes the restoration time frames based on the analysis in Section 9. The values for "restoration time frame" are identical to the values for "time to achieve cleanup objectives" presented in Sections 9 and 10. As discussed in Sections 9 and 10, no alternative achieves the PRGs for RAO 1; thus, an alternative measure of the lowest long-term model-predicted concentrations is used to represent levels as close as practicable to PRGs for the purpose of this analysis. Alternatives 3C, 4C, 5C, and 6C are predicted to achieve cleanup objectives for the four RAOs in the shortest time (16 to 18 years after construction begins). Alternatives 2R, 2R-CAD, 3R, 4R, 5R, and 5R-Treatment are predicted to take moderately longer (21 to 24 years after construction begins) to achieve the cleanup objectives because of their reliance on dredging, which takes longer to implement than capping and ENR/*in situ*. Finally, Alternative 6R takes the longest time (42 years) because of its long construction period and the ongoing impacts to fish and shellfish tissue concentrations during construction.

Alternative 6R is the only alternative considered to not have a reasonable restoration time frame. Alternatives 2 through 6C are assumed to have reasonable restoration time frames based on the nine factors in WAC 173-340-360(4)(b). All of the alternatives are retained for the DCA evaluation.

As discussed elsewhere in this FS, many uncertainties are associated with the estimated restoration time frames. To some degree, these uncertainties could be managed through monitoring coupled with adaptive management, which would provide information during construction to assess risks and progress toward achieving the MTCA cleanup levels. This assessment could allow for adjustments in cleanup technologies to try to practicably achieve these levels in locations where the initial effort did not achieve RALs. Adaptive management measures are included in Alternatives 2 through 6 to allow additional areas to be identified and managed by alternative means as needed, including areas that may still exceed SMS criteria after 10 years. These measures are incorporated into the cost estimates for the alternatives, but are not incorporated into construction time frames or restoration time frames, and thus may increase remediation times beyond those predicted in this FS.

## 11.5 Disproportionate Cost Analysis

MTCA requires that remedial alternatives use permanent solutions to the maximum extent practicable. For example, alternatives that include more dredging remove more contaminated sediment from the LDW, which provides a more permanent solution than alternatives that leave more contaminated sediment in the LDW. However, dredging is more expensive than capping, and capping is more expensive than ENR, which is in turn more expensive than MNR. The DCA is a MTCA procedure to evaluate tradeoffs, including costs, among technologies that is more specific than CERCLA's general nine criteria analysis. It was specifically created to weigh incremental environmental benefits against the incremental cost of such benefits. This determination is made based on the DCA process in which: 1) the most practicable, permanent remedial alternative serves as the baseline; and 2) the benefits of the remedial alternatives to human health and the environment are evaluated and compared to the costs. This analysis uses the evaluation criteria listed in WAC 173-340-360(3)(f). Both quantitative measures and more qualitative best professional judgments are used in assessing benefits (WAC 173-340-360(3)(e)(ii)(C)). The metrics used in the DCA are described in Table 11-4. Results of the DCA are summarized in Table 11-5. Table 11-6 provides the detailed metrics and scoring for each evaluation criterion.

Each aspect of the DCA scoring requires professional judgment. Quantitative measures were used where possible.

### 11.5.1 Weighting of MTCA Evaluation Criteria

The MTCA evaluation criteria presented in WAC 173-340-360 (3)(f) were weighted in consultation with Ecology (Table 11-4). The weightings emphasize the core purpose of protecting human health and the environment and reflect site-specific considerations, such as the size, complexity, uncertainty, and potential restoration time frames involved in the remedial alternatives. The sum of the weightings equals 100%.

"Protectiveness" represents the ultimate objective of implementing a remedial alternative. Therefore, overall protectiveness ratings were weighted 25%.

A weighting of 20% was assigned to the "permanence" criterion. In evaluating the alternatives under this criterion, MTCA focuses on the degree that the toxicity, mobility, or volume of hazardous substances is reduced, and considers the extent to which contamination is removed from the LDW rather than leaving it buried in place.

"Effectiveness over the long term" is an important requirement because it addresses how well the remedy reduces risks, for example, whether contamination is removed or left in place to be managed over the long term, and whether controls are adequate to maintain protection against exposures to contamination left in place in the long term. This criterion therefore received a weighting of 30%.

A weighting of 15% was assigned to the "management of short-term risk" criterion. This weighting considers the relatively long durations of most of the remedial alternatives. Because of the extended time frames for alternatives with larger active remediation footprints, short-term risks to workers, the community, and the environment can extend for many years. Generally, short-term risks are actively monitored during the period the risks exist.

A weighting of 5% was assigned to the "technical and administrative implementability" criterion. This weighting reflects the fact that implementability is less associated with environmental concerns than with the relative difficulty and uncertainty of implementing the project. It includes both technical factors and the administrative factors associated with permitting and completing the cleanup.

Consideration of public concerns is assigned a weighting of 5%. This weighting reflects that most public concerns are embodied by the other criteria of the DCA. In other words, the degree of risk reduction, the long-term reliability, the community and environmental impacts during construction, and cost to the local economy are all represented in public comments and in the other metrics of the DCA. Public concern rankings in the DCA provide a summary of these community concerns, based on public comments and stakeholder meetings for the FS.

Cost is not a weighted benefit, but is used in the DCA to evaluate the benefit of each alternative relative to its cost.

### 11.5.2 DCA Evaluation for Remedial Alternatives

Table 11-5 provides a summary of how well the remedial alternatives rate on a scale from 0 to 10 for each MTCA criterion. The following evaluations provide the basis for the numerical ratings in the DCA. These ratings are then weighted and summed for an overall measure of the benefits achieved by the alternatives, presented in Table 11-5, along with the cost estimates (as net present value) for each remedial alternative. Table 11-6 provides the metrics used to develop the ratings summarized in Table 11-5. Each metric includes the unit used for each alternative (e.g., years, cubic yards, or acres), as well as the representative value that would receive a score from 0 to 10. In general, a score of 0 represents a poor-performing alternative for that metric, and a score of 10 represents an optimal performing alternative for that metric. Note that depending on the basis for a metric's scale, the alternatives may not always cover the full range (0 to 10) if they all have less than optimal results for that measure.

The goal of Table 11-6 is to select benefit metrics for each DCA evaluation criterion such that the benefit metrics reasonably reflect the DCA criteria. Some metrics appear more than once because the selected metric is a surrogate measure of the value statement for each line item in the DCA, or because the same metric is directly applicable to multiple MTCA-defined criteria. For example, risks during implementation appear under both overall protectiveness and management of short-term risks. This ensures that each DCA criterion is quantified and contributes to the overall benefit scoring.

A significant number of choices were made in selecting each metric and selecting the scoring range (defining what 0 and 10 represent). These choices were made using best professional judgment; however, scoring the "benefit" of each remedial alternative is somewhat subjective. These scores provide a useful tool for comparing remedial alternatives, but do not provide an absolute or precise measurement of benefit. Small differences in overall benefit scores should therefore be considered to have limited significance.

The following subsections describe the MTCA DCA criteria as defined by WAC 173-340-360 and the metrics that were used to evaluate each alternative's performance relative to that metric in the DCA.

#### 11.5.2.1 Protectiveness

In MTCA, protectiveness is evaluated based on the degree to which existing site risks are reduced, the time required to reduce those risks and to achieve cleanup standards, and on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality. For the LDW, protectiveness was quantified using three metrics: total human health exposure risks, cumulative benthic exposure risks, and risks during implementation.

***Degree to which Existing Risks are Reduced, Overall Improvement in Environmental Quality, and the Time to Achieve Cleanup (Metrics 1a and 1b: Cumulative Exposure and Cumulative Benthic Exposure)***

Metrics for assessing the degree to which LDW-wide risks are reduced, the overall improvement in environmental quality, and the time to achieve cleanup standards were based on milestones for RAOs 1 and 3. This equal weighting assumes that protection of human health and protection of benthic invertebrates are of equal importance; a different balance could well have been used, elevating the importance of one above the other. This choice, like the choice to eliminate RAOs 2 and 4 from this criterion, and other choices throughout the DCA, illustrate how different users may validly apply the DCA tool differently. To assess these criteria for each remedial alternative, the predicted total PCB spatially-weighted average concentration (SWAC) (RAO 1; Figure 10-1a) and the predicted number of SQS point exceedances (RAO 3, Figure 10-2) were integrated over a 45-year time span based on the restoration time frame for Alternative 6R. This 45-year period includes both the time required to construct each alternative (see Table 11-3) and a post-construction recovery period that varies from 42 years (Alternative 3) to 3 years (Alternative 6R).

For Metric 1a, total PCB SWACs were used as a surrogate for cumulative exposure for seafood consumption risk from fish and shellfish tissue contaminant concentrations over time. The BCM 5-year outputs presented in Table 9-2a were used to calculate the SWACs. A low score of 0 represented natural recovery without construction (i.e., Alternative 1), and a high score of 10 represented an unlikely achievable site-wide PCB SWAC equivalent to the long-term model-predicted SWAC (39 µg/kg dw) within 5 years after the start of construction, and held at 39 µg/kg dw for the next 40 years (although it is possible that a lower level will be achieved at some point in the future). Fish and shellfish contaminant concentrations (and the associated seafood consumption risks) are predicted to increase during dredging activities. These calculations do not include these effects and therefore may understate risks throughout the construction period, particularly for alternatives with larger dredging footprints.

In Metric 1b, predicted SQS exceedances were integrated over a 45-year time span. A score of 0 represented natural recovery without construction (i.e., Alternative 1), and a score of 10 represented SQS exceedances reduced to 0 within 5 years after the start of construction, and held at no exceedances for the next 40 years.

Alternatives 5C and 6C score highest for these two metrics because they strike a balance between relatively large areas actively remediated and relatively short construction time frames. Alternatives with smaller active remedial footprints and longer construction time frames scored lower.

#### *Risks from Implementation (Metric 1c)*

As noted in Section 11.3.1, implementing the remedial alternatives causes construction-related environmental risks such as mobilization of contaminants during construction. Risks from implementation include a number of factors that are proportional to the total construction time. Risks to the community, construction workers, and the environment are simplified into one metric (the construction time) that represents several metrics, such as:

- Impacts to workers and the community from dredging and transporting sediment and capping materials
- Air pollution generated and depletable resources consumed (environmental impacts)
- The expected short-term increases of contaminant concentrations in fish and shellfish tissue in and near the LDW and associated increased risks to people who consume resident seafood during that period (community risks)
- Releases of contaminants from the site, and disruptions to aquatic habitat (environmental risks).

The implementation risks to the community are largely attributable to the increased construction-related traffic through local communities, along with risks to those people who choose to consume resident seafood that will have elevated tissue concentrations during the construction period despite the existing Washington State Department of Health advisory warning not to eat any. The latter risks could perhaps be reduced by using more robust seafood consumption advisories to reduce exposure to contaminants in resident seafood during construction.

The evaluation of environmental risks includes the quantitative impacts on the environment both from air pollution generated by construction activities and depletable resources consumed, as well as the expected short-term increases of contaminant concentrations in fish and shellfish tissues, and physical destruction and necessary restoration of aquatic habitat. Increased resuspension of sediment associated with construction is anticipated to result in higher contaminant concentrations in fish and shellfish tissues during construction. In addition, the recovery time of benthic habitat in areas may be greatly affected by the degree to which the existing sediment habitat is impacted, the total area impacted, and the degree to which the habitats are contiguous.

For the purposes of this analysis, all of these risks are assumed to be directly proportional to the duration of active construction. This is appropriate because the amount of construction activity (and associated impacts) per construction season would be similar for all of the alternatives. Therefore, the net impacts from implementation would be proportional to the construction time frame for each alternative. A score of 0 represents the longest construction time frame of the remedial alternatives (Alternative 6R: 42 yrs); a score of 10 represents no construction following the remediation of the early action areas (Alternative 1).

For Metric 1c, Alternatives 1 through 6 score progressively lower, and removal alternatives score lower than combined alternatives, indicating greater risks during implementation for the removal-emphasis alternatives with larger active footprints.

***Overall Scores for Protectiveness***

The preceding three metrics (1a, 1b, and 1c) are averaged using the weighting factors shown in Table 11-6. These weighting factors express the relative importance of the metrics using best professional judgment. Overall, the combined alternatives score slightly higher than the removal alternatives because they are predicted to achieve comparable risk reduction in shorter time frames with fewer implementation risks. The alternatives with larger active footprints tend to score higher than alternatives with smaller active footprints (e.g., Alternative 6C versus Alternative 3C). The exceptions are Alternatives 5R and 6R, which score the same or lower than Alternative 4R because of the greater impacts over their longer construction periods.

#### 11.5.2.2 Permanence

MTCA defines permanence as the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment processes, and the characteristics and quantity of waste residuals generated.

For the LDW, rating the alternatives for permanence is not completely straightforward because none of the remedial alternatives destroys contaminants; rather, they do one of the following: 1) contain the contaminated material within the LDW thereby reducing its toxicity and mobility; 2) remove it to a landfill (all alternatives in varying degrees), thereby eliminating its toxicity, mobility, and volume with respect to site receptors; 3) move it to a CAD (Alternative 2R-CAD); or 4) segregate it into more and less contaminated fractions before sending the higher contaminated material to the landfill and placing the less contaminated material back into the environment (soil washing in Alternative 5R-Treatment). Removal of contaminated sediments to a landfill ranks higher for this criterion than leaving contamination within the LDW where it could potentially be exposed due to anthropogenic events (e.g., excavation or ship scour) or natural events (e.g., an earthquake).

For this analysis, two metrics were selected to represent permanence. The first metric (2a) is volume of sediment removed from the LDW. This metric was scaled from 0 cy (score 0), based on no sediment removal, to 3.9 million cy (score 10), based on the removal of material above the Alternative 6 RALs for Alternative 6R. For this metric, the removal-emphasis alternatives score significantly higher than the combined-technologies alternatives, and alternatives with larger active footprints score higher than alternatives with smaller active footprints (e.g., Alternative 6R versus Alternative 2R).

The second metric (2b) ranks the reduction in contaminant mobility in the LDW based on the acres of each remedial technology used. For this analysis, dredging (removal) and capping were assumed to reduce mobility more than the other technologies (scores of 9 and 8 respectively), *in situ* treatment was assumed to reduce mobility more than a moderate amount (score 7), ENR was assumed to reduce mobility a moderate amount (score 4), and MNR and verification monitoring were assumed to reduce mobility to a lesser degree (score 2). Burial is the mechanism by which ENR, MNR, and verification monitoring reduce mobility; monitoring and adaptive management (i.e., contingency actions) ensure that contaminated sediment is immobilized sufficiently. *In situ* treatment further reduces mobility by adding amendments that bind or retard contaminants. This metric scores similar to the previous metric: the removal-emphasis alternatives score significantly higher than the combined-technologies alternatives, and the alternatives with larger active footprints score higher than the alternatives with smaller active footprints.

#### 11.5.2.3 Effectiveness over the Long Term

The effectiveness of the remedial alternatives over the long term is evaluated under MTCA by considering the following components:

- Degree of certainty that the remedial alternative will be successful
- Reliability of the alternative over the period during which risk-driver contaminants remain on site (including subsurface contamination) at concentrations higher than PRGs (or cleanup levels)
- The magnitude of residual risk
- Reliability of institutional controls and engineering controls used to manage risks to the extent they are necessary
- Cleanup and disposal methods hierarchy listed in WAC 173-340-360(3)(f)(iv).

For the LDW, these components are simplified and scored by the weighted average of two metrics: 1) the degree of certainty that the remedial alternatives will be successful and 2) the reliability of controls to manage risks. These metrics are shown in Table 11-6 and summarized below.

#### *Degree of Certainty that the Remedial Alternatives Will Be Successful (Metric 3a)*

As noted in Section 9.3.5 and elsewhere in the FS, the predicted outcomes and success of remediation for all remedial alternatives have some uncertainty, particularly those that rely more on natural recovery. Uncertainties include the effectiveness of source control, the rates of natural recovery, concentrations of incoming sediment from upstream and lateral sources, and the effectiveness of remedial technologies (see discussion in Sections 8.4 and 9.3.5). Some of these uncertainties are the same for all remedial alternatives, such as the actual contaminant concentrations in upstream sediment. However, uncertainties related to the effectiveness of specific remedial technologies (including MNR) will affect the alternatives to different degrees. Therefore, the remedial alternatives were scored based on the remedial technologies that would be employed.

For this metric (3a), each remedial technology is weighted based on best professional judgment. This analysis assumed that the remedial technologies that depend on construction only (i.e., capping and dredging) have a higher degree of certainty of success than remedial technologies that depend on natural recovery (i.e., ENR and MNR). Dredging scores a 9 because, while it would remove a significant degree of contamination from the LDW, removal would not be perfect in practice and some contamination would be left following dredging (e.g., due to dredge residuals or losses during dredging). Capping scores 9 because it would isolate contaminated sediment, but contaminated sediment would remain on site with a chance of exposure. *In situ* treatment scores 7 because it would not provide full containment, like a cap, but would reduce the possibility of contaminant breakthrough and uptake by adding a carbon amendment. ENR scores 6 because it depends on natural recovery, but also achieves additional protectiveness with a thin layer of sand. MNR and verification monitoring score 3 because they depend on natural recovery. However, monitoring and adaptive management could improve areas that do not achieve performance goals. (As noted above, adaptive management measures are incorporated into the cost estimates for the alternatives, but are not incorporated into construction time frames or restoration time frames, and thus may increase remediation times beyond those predicted in this FS.) The remedial alternatives are scored based on the weighted average of the acreage for each technology used in Area of Potential Concern 1 (AOPC 1). For example, if an alternative assigned dredging to all of AOPC 1, then the alternative would score a 9, and if the alternative assigned MNR to all of AOPC 1, it would score a 3. Half dredging and half MNR would score a 6.

Table 11-6 shows the scores for Metric 3a for the remedial alternatives. The removal-emphasis alternatives score higher than the combined-technologies alternatives, and the alternatives with larger active footprints score higher than the alternatives with smaller active footprints (e.g., Alternative 6 scores higher than Alternative 2).

***Reliability of Institutional Controls and Engineering Controls Used to Manage Risks (Metric 3b)***

All remedial alternatives would use similar institutional and engineering controls to manage risk. However, the degree to which they need to use these controls would differ. Institutional controls include seafood consumption advisories, public outreach and education programs, and environmental covenants and restricted navigation areas as described in Section 7. Alternatives 2 through 6 would all rely on seafood consumption advisories to address residual risks associated with RAO 1. Seafood consumption advisories would remain in effect for all remedial alternatives. However, the alternatives vary significantly in the degree to which environmental covenants would be relied upon.

Therefore, reliability was mainly scored based on engineering controls, which would be needed to manage and monitor contaminants remaining on site. Alternatives with more dredging received higher scores both because removal of contaminants is a more reliable technology in the long term and because it does not rely on covenants or other devices to address potential exposure of contaminants left in place. This metric (3b) is scored as a proportion of the surface area where buried contamination potentially remains on site. For this metric, the acres with caps, ENR/*in situ*, MNR, and verification monitoring in AOPC 1 are summed for each alternative. Alternative 2R-CAD includes the CAD area. The metric is scored from none of AOPC 1 removed (score 0) to all of AOPC 1 removed (score 10). The removal-emphasis alternatives score higher than the combined-technologies alternatives for this metric, and the alternatives with larger active footprints score higher than the alternatives with smaller active footprints.

***Overall Score for Effectiveness over the Long Term***

Metrics 3a and 3b were averaged using the weighting factors shown in Table 11-6. These weightings show the relative importance of the metrics using best professional judgment. Overall, the result is that the removal-emphasis alternatives score higher than the combined-technologies alternatives, and the alternatives with larger active footprints score higher than the alternatives with smaller active footprints.

### 11.5.2.4 Management of Short-term Risks

Short-term risks to human health and the environment occur during construction and implementation. This criterion uses two components: the risks presented by the implementation of the remedial alternative and the effectiveness of the protective measures used to manage those short-term risks. These components are the metrics used in the FS to compare the remedial alternatives.

#### *Implementation Risks (Metric 4a)*

Implementation risks (Metric 4a) are assumed to be equivalent to the metric for risks from implementation (Metric 1c) discussed in Section 11.5.2.1, which are directly proportional to construction time frames.

#### *Effectiveness of Protective Measures to Manage Short-term Risks (Metric 4b)*

The second metric (4b) rates the effectiveness of protective measures such as institutional controls and best management practices that would be used to mitigate the risks associated with the remedial alternatives during construction.

For this analysis, the FS assumes that the same types of protective measures are used for all alternatives; therefore, the effectiveness of these protective measures is inversely proportional to the construction time frame of the remedial alternative. The alternatives with the shortest construction time frame ranked the highest and those with the longest construction time frames ranked the lowest.

#### *Overall Score for Management of Short-Term Risks*

The construction time frames and relative rankings of the alternatives are shown in Table 11-6. Alternatives rate progressively lower from Alternatives 2 through 6 and rate lower for removal-emphasis alternatives than for combined-technologies alternatives.

### 11.5.2.5 Technical and Administrative Implementability

Implementability under MTCA has several components, including technical feasibility; availability of necessary off-site facilities, services, and materials; administrative and regulatory requirements; scheduling, size, and complexity; monitoring requirements; access for construction and operation and maintenance monitoring; and integration with existing facility operations and other remedial actions. Each component is taken into account and a rating is given to each remedial alternative based on best professional judgment.

Alternatives 5R-Treatment and 6R are rated lowest because they are considered more challenging to implement: Alternative 5R-Treatment because of the difficulty of treating and reusing contaminated sediment and Alternative 6R because of the very large scope of remediation. Alternatives 2R-CAD, 5R, and 6C are rated in the middle: Alternative 2R-CAD because of the difficulty of implementing a CAD in the LDW and Alternatives 5R and 6C because of the relatively large scope of dredging. Alternatives 2R, 3C, and 3R are rated higher because of reliance on MNR to achieve cleanup objectives. Alternatives 4C, 4R, and 5C score the highest because of the relative balance between reliance on MNR and the scope of dredging.

### 11.5.2.6 Consideration of Public Concerns

The public involvement process under MTCA and CERCLA is used to identify public preferences and concerns regarding the remedial alternatives. This includes concerns raised by individuals, community groups, local governments, local businesses, tribes, federal and state agencies, and anyone who may have an interest in the site. Issuance of the Proposed Plan will provide an additional opportunity for identifying public comments, concerns, and feedback. This criterion will ultimately be evaluated by EPA and Ecology in the selection of the preferred alternative in the ROD.

Based on preliminary feedback to date on the draft final FS, Alternative 6R scores the highest because most of the comments received favored more removal. Remedial alternatives that have relatively large cleanup scopes and rely less on MNR (Alternatives 5C, 5R, 5R-Treatment, and 6C) are scored high because they also had large volumes removed. The smaller cleanups (Alternatives 2R, 2R-CAD, and 3R) were rated lower. Alternative 3C also received favorable comments and was therefore scored higher. Although Alternatives 3C has a smaller active footprint (along with 4C and 4R), it achieves the greatest risk reduction of all of the alternatives within the shortest construction time frame.

#### 11.5.2.7 Costs

Estimated costs to implement the remedial alternatives are presented in Appendix I (on a net present value basis). These cost estimates and their associated total weighted benefits can be used by the Agencies to determine whether a remedial alternative's costs are disproportionate to the benefits provided by the alternative. The costs are presented in Tables 11-3 and 11-5 and are shown with the total benefits ratings on Figures 11-1 through 11-3. While EPA does not use the DCA methodology in its consideration of costs in remedy selection, EPA may consider it. Among the factors EPA would most critically consider is the extent to which accurate values are believed to have been assigned to the various DCA criteria.

### 11.5.3 Relative Benefits and Costs for Treatment Technology

By comparing Alternative 5R with Alternative 5R-Treatment, a direct comparison of upland landfill disposal and soil washing treatment can be made. A review of the scoring of the two alternatives shows that Alternative 5R scores slightly higher for benefit and is slightly lower in cost, indicating that soil washing treatment benefits may be slightly disproportionate to costs.

For informational purposes, the estimated additional cost associated with adding soil washing treatment to all alternatives is shown in Table 11-7.

### 11.5.4 Summary of DCA Results

Table 11-5 summarizes the DCA and calculated cost/benefit ratios for Alternatives 2 through 6. Considering all of the ratings from the DCA evaluation, the total benefit scores range from 3.8 to 6.6 for the remedial alternatives. The total benefit scores indicate that more dredging has other adverse effects that do not result in higher overall scores, even though more dredging scores the highest in permanence and effectiveness over the long term. More reliance on containment has other benefits that result in higher scores, especially short construction times relative to dredging and reduction of potential resuspension that occurs during dredging.

Weighted benefits that differ by small amounts should be considered equivalent because the large degree to which best professional judgment plays a role in the analysis does not allow for precision and because simplifying assumptions used in evaluating criteria may obscure some differences among alternatives.

A series of figures are provided that interpret the results of the DCA. Figure 11-1 shows the weighted benefit score for each alternative with an overlay of cost. The total benefits for the remedial alternatives range from 3.8 to 6.6, and costs range from $200 to $810 million net present value (see Appendix I for cost details). More expensive alternatives do not necessarily show proportional increases in overall benefit.

Figure 11-2 plots benefits versus the cost for the alternatives. This graphic shows the same benefit rankings as Figure 11-1, but provides a visual representation of the spread of costs. This figure also indicates that added cost does not necessarily translate into proportional overall benefits.

Figure 11-3 plots benefits versus the cost for the alternatives, but normalizes the benefits and costs from the lowest to the highest of the remedial alternatives on a scale from 1 to 10. For example, the least expensive alternatives, Alternatives 2R-CAD and 3C ($200 million), are shown as a 0, and the most expensive alternative, Alternative 6R ($810 million), is shown as a 10. The other alternatives are plotted on the same 1 to 10 scale.

The analysis presented in this section is intended to support Ecology in its evaluation of the remedial alternatives relative to MTCA. Figures 11-1 through 11-3 provide various approaches to identify where costs may be disproportionate to benefits. The final identification of the remedial alternative that uses "permanent solutions to the maximum extent practicable" will be made in the ROD.

MTCA states that "costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower alternative exceed the incremental degree of benefits achieved by the alternative over that of the lower cost alternative" (WAC 173-340-360(3)(e)(i)), and that "Where two or more alternatives are equal in benefits, the department shall select the less costly alternative" (WAC 173-340-360(3)(e)(ii)(C)). Although the results of the DCA should be interpreted with caution, the results indicate that, at a minimum, Alternative 6R is disproportionately costly compared to its benefits in relation to the other remedial alternatives.

**Table 11-1 Schematic of the MTCA Remedy Selection Process**

| MTCA Minimum Requirements for Cleanup Actions (WAC 173-340-360(2)) | MTCA Cleanup Regulation | Description and Applicability | Evaluation Procedure |
|---|---|---|---|
| ***Threshold Requirements*** | | | Alternatives are initially screened against "threshold requirements" ↓ |
| Protect human health and the environment | WAC 173-340-360(2)(a)(i) | Threshold requirements are the initial screening of remedial alternatives. Threshold requirements are addressed in Section 11.3. | |
| Comply with cleanup standards | WAC 173-340-360(2)(a)(ii) | | |
| Comply with applicable state and federal laws | WAC 173-340-360(2)(a)(iii) | | |
| Provide for compliance monitoring | WAC 173-340-360(2)(a)(iv) | | |
| ***Other Requirements (except using permanent solutions to the maximum extent practicable, which is evaluated last)*** | | | Alternatives are screened against the additional "minimum requirements" ↓ |
| Provide for a reasonable restoration time frame | WAC 173-340-360(2)(b)(ii) | Remedial alternatives are screened for reasonable restoration time frame in Section 11.4. | |
| Consider public concerns | WAC 173-340-360(2)(b)(iii) | Considerations of public concerns are included in the MTCA process and are not addressed in a separate part of Section 11. The FS will be open to public comment for a period following publication, and public concerns will be incorporated into the final decision documents. | |
| ***Additional Minimum Requirements*** | | | |
| Groundwater cleanup actions | WAC 173-340-360(2)(c) | Not applicable to the FS. | |
| Soil at residential areas, schools, and child care centers | WAC 173-340-360(2)(d) | | |
| Institutional controls | WAC 173-340-360(2)(e) | These additional minimum requirements serve to screen remedial alternatives and are addressed in Sections 11.2.3. | |
| Releases and migration | WAC 173-340-360(2)(f) | | |
| Dilution and dispersion | WAC 173-340-360(2)(g) | | |
| Remediation levels | WAC 173-340-360(2)(h) | | |
| ***Additional Other Requirement (DCA) (evaluated last)*** | | | Alternatives that pass other "minimum requirements" are compared using the DCA. |
| Use of permanent solutions to the maximum extent practicable – disproportionate cost analysis (DCA) | WAC 173-340-360(2)(b)(i) | The DCA provides a tool for the comparison of alternatives that pass the other "minimum requirements," and is addressed in Section 11.5. | |

Notes:

DCA = disproportionate cost analysis; FS = feasibility study; MTCA = Model Toxics Control Act; WAC = Washington Administrative Code

## Table 11-2 Cross Reference of MTCA Threshold and Other Minimum Requirements to Sections of the FS

| MTCA Minimum Requirements for Remedial Alternatives (WAC 173-340-360(2)) | MTCA Evaluation Factors | FS Section in Which Requirement is Evaluated |
|---|---|---|
| ***Threshold Requirements (WAC 173-340-360 (2)(a))*** | | |
| i. Protect human health and the environment<br>WAC 173-340-360(3)(f)(i) | • Degree to which existing risks are reduced<br>• Time required to reduce risks and achieve cleanup standards<br>• On-site and off-site risks from implementing alternative<br>• Improvement in overall environmental quality | • Alternatives are evaluated in Section 11.3.<br>• Tables 9-2 through 9-8 and alternative summary tables and figures in Section 9 provide the predicted numerical reductions in risk-driver concentrations for each alternative over time.<br>• Section 9 contains evaluations of on-site and off-site risks, as well as time to achieve cleanup objectives for the RAOs. |
| ii. Comply with cleanup standards<br>WAC 173-340-760 | • Remediation levels (WAC 173-340-355)<br>• No significant health risk to humans (site specific) (173-340-320 (4))<br>SMS criteria:<br>• Cleanup objective 173-204-570 (2)<br>• No adverse effects on biological resources (173-204-320 (2))<br>• Minimum Cleanup Level (173-204-570(3)) | • Alternatives are evaluated in Section 11.3.<br>• RAOs and PRGs are presented and discussed in Section 4.<br>• RALs developed in Section 6 are used to develop alternatives in Section 8.<br>• Section 11.2 discusses MTCA cleanup standards, and remediation levels compared to PRGs and RALs. |
| iii. Comply with applicable state and federal laws.<br>WAC 173-340-710 | • ARARs | • Alternatives are evaluated in Section 11.3.<br>• ARARs are discussed in Section 9.1.1.2. |
| iv. Provide for compliance monitoring<br>WAC 173-340-410 and 173-340-760 | • Protection Monitoring<br>• Performance Monitoring<br>• Confirmational Monitoring | • Alternatives are evaluated in Section 11.3.<br>• Conceptual monitoring scope is developed in detail in Appendix K for costing purposes, and is discussed in Section 8 for each remedial alternative. |

**Table 11-2 Cross Reference of MTCA Threshold and Other Minimum Requirements to Sections of the FS (continued)**

| MTCA Minimum Requirements for Remedial Alternatives (WAC 173-340-360(2)) | MTCA Evaluation Factors | FS Section in Which Requirement is Evaluated |
|---|---|---|
| ***Other Requirements (WAC 173-340-360(2)(b))*** | | |
| i. Use permanent solutions to the maximum extent practicable | • Disproportionate Cost Analysis 173-340-360(3)(e) | • Discussed in Section 11.5 "Practicability" determined through the Disproportionate Cost Analysis (DCA). |
| ii. Provide for a reasonable restoration time frame | • 173-340-360(4)(b)<br>• Potential risks posed by the site<br>• Practicability of achieving a shorter restoration time frame<br>• Uses & resources that are or may be affected by releases from the site<br>• Effectiveness & reliability of institutional controls<br>• Ability to control and monitor migration<br>• Toxicity of the hazardous substances at the site<br>• Natural processes that reduce concentrations and have been documented to occur at the site or under similar site conditions | • Restoration time frame is evaluated in Section 11.4.<br>• Potential baseline site risks are summarized in Section 3.<br>• Restoration time frames are discussed in Section 9 and are presented in Table 11-3.<br>• The potential for elevated fish and shellfish tissue concentrations during and after construction activities is discussed in Section 9 for each alternative.<br>• Institutional controls, monitoring, and adaptive management are discussed in detail in Appendix K and Section 7, and discussed in Section 8 for each alternative.<br>• Time to achieve cleanup objectives for alternatives that rely on MNR is discussed in Section 9 for each alternative. The BCM (Section 5) is used to predict recovery potential. |
| iii. Consider public concerns | • Consideration of public concerns is part of the FS process and will be formally evaluated during development of the Record of Decision. | • Discussed in Section 9.1.3. |

Notes:

ARAR = applicable or relevant and appropriate requirements; BCM = Bed Composition Model; DCA = disproportionate cost analysis; FS = Feasibility Study; MNR = monitored natural recovery; MTCA = Model Toxics Control Act; PRG = preliminary remediation goal; RAL = remedial action levels; RAO = remedial action objectives; WAC = Washington Administrative Code

## Table 11-3 Compliance with Minimum Requirements

| | Requirement | | | Remedial Alternative | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2R | 2R-CAD | 3C | 3R | 4C | 4R | 5C | 5R | 5R-T | 6C | 6R |
| *Threshold Requirements* | **Protection of human health and the environment and compliance with cleanup standards (Sections 11.3.1 and 11.3.2)** | | | | | | | | | | | | | | |
| *Threshold Requirements* | **Risk Pathway Category** | | **Preliminary Cleanup Standard**[a] | **Compliance** | | | | | | | | | | | |
| *Threshold Requirements* | Human Health | RAO 1: Human Health – Seafood Consumption | Preliminary CULs = PRGs with a POC of the upper 10 cm of site-wide sediment on a SWAC basis | Not achieved | Cleanup standards achieved through a combination of active remediation, source control, natural recovery, and institutional controls; see Table 10-1 | | | | | | | | | | |
| *Threshold Requirements* | Human Health | RAO 2: Human Health – Direct Contact | Preliminary CULs = PRGs with a POC of the upper 45 cm of sediment as a SWAC in beaches and potential clamming areas, and the upper 10 cm of site-wide sediment on a SWAC basis | Cleanup standards achieved; see Table 10-1[b] | | | | | | | | | | | |
| *Threshold Requirements* | Environment | RAO 3: Ecological Health – Benthic | Preliminary CULS = PRGs (SQS) with a POC of the upper 10 cm of site-wide sediment on a point basis | Cleanup standards achieved; see Table 10-1 | | | | | | | | | | | |
| *Threshold Requirements* | Environment | RAO 4: Ecological Health – Seafood Consumption – River Otter | Preliminary CULS = PRGs with a POC of the upper 10 cm of site-wide sediment on a SWAC basis | Cleanup standards achieved; see Table 10-1 | | | | | | | | | | | |
| *Threshold Requirements* | **Compliance with applicable local, state, and federal laws (Section 11.3.3)** | | | Not achieved | Complies with all applicable local, state, and federal laws; see Table 10-1 | | | | | | | | | | |
| *Threshold Requirements* | **Provide for compliance monitoring (Section 11.3.4)** | | | Not achieved | Conceptual monitoring plan for Remedial Alternatives 2 through 6 is provided in Appendix K | | | | | | | | | | |
| *Threshold Requirements* | **Achieves threshold requirements? (Section 11.3.5)** | | | **No** | **Yes** | | | | | | | | | | |
| *Other Requirements* | **Restoration Time Frames (RTF; years)**[c] **(Section 11.4)** | | | | | | | | | | | | | | |
| *Other Requirements* | Duration of construction period | | | n/a | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| *Other Requirements* | RAO 1 | | | n/a | 24 | 24 | 18 | 21 | 21 | 21 | 17 | 22 | 22 | 16 | 42 |
| *Other Requirements* | RAO 2 (total/individual risk drivers) | | | n/a | 4/19 | 4/19 | 3/3 | 4/6 | 3/3 | 4/6 | 3/3 | 4/6 | 4/6 | 3/3 | 4/6 |
| *Other Requirements* | RAO 3 | | | n/a | 14 | 14 | 8 | 11 | 6 | 11 | 6 | 11 | 11 | 6 | 11 |
| *Other Requirements* | RAO 4 | | | n/a | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| *Other Requirements* | **Consideration of public concerns (Section 11.5.2.6)** | | | n/a | Consideration of public concerns is part of the Feasibility Study process and is evaluated as part of the DCA. | | | | | | | | | | |
| *Additional Minimum Requirements* | **Groundwater cleanup actions** | | | n/a | Not applicable to Feasibility Study | | | | | | | | | | |
| *Additional Minimum Requirements* | **Soil at residential areas, schools, and child care centers** | | | n/a | Not applicable to Feasibility Study | | | | | | | | | | |
| *Additional Minimum Requirements* | **Institutional controls (Section 11.2.3)** | | | n/a | Achieved | | | | | | | | | | |
| *Additional Minimum Requirements* | **Releases and migration (Section 11.2.3)** | | | n/a | Achieved | | | | | | | | | | |
| *Additional Minimum Requirements* | **Dilution and dispersion (Section 11.2.3)** | | | n/a | Achieved | | | | | | | | | | |
| *Additional Minimum Requirements* | **Remediation levels (Section 11.2.3)** | | | n/a | Achieved | | | | | | | | | | |
| *DCA* | Weighted Benefit Points (score from Table 11-6) | | | n/a | 4.2 | 3.8 | 5.0 | 4.9 | 5.8 | 5.8 | 6.5 | 6.4 | 6.2 | 6.6 | 6.2 |
| *DCA* | Cost ($millions net present value) (Section 11.5.2.7) | | | n/a | 220 | 200 | 200 | 270 | 260 | 360 | 290 | 470 | 510 | 530 | 810 |
| *DCA* | Benefit points per $billion (Section 11.5.3) | | | n/a | 19 | 19 | 25 | 18 | 22 | 16 | 22 | 14 | 12 | 12 | 7.7 |

Notes:

a. Preliminary cleanup standards are considered to be equivalent with PRGs.

b. Alternatives achieve total direct contact excess cancer risk of $1 \times 10^{-5}$ for all scenarios. Total PCBs and dioxins/furans achieve direct contact excess cancer risk of $10^{-6}$ for all scenarios. Arsenic PRGs are equal to natural background, with excess cancer risks between $1 \times 10^{-6}$ and $1 \times 10^{-5}$ for all scenarios. cPAHs achieve $1 \times 10^{-6}$ excess cancer risk for all scenarios except in Beach 3 for beach play direct contact, due to lateral loads.

c. Estimated restoration time frame is equivalent to the time to achieve cleanup objectives developed in Section 9. The restoration time frame is the longest duration shown in Table 9-24 for each RAO.

C = combined-technology alternatives; cPAH = carcinogenic polycyclic aromatic hydrocarbon; CUL = cleanup level; DCA = disproportionate cost analysis; n/a = not applicable; PCB = polychlorinated biphenyl; POC = point of compliance; PRGs = preliminary remediation goals; R = removal-emphasis alternatives with upland disposal; RAO = remedial action objective; R-CAD = removal-emphasis alternative with contained aquatic disposal; R-T = removal-emphasis alternative with soil washing; RTF = restoration time frame; SQS = sediment quality standards; SWAC = spatially-weighted average concentration

## Table 11-4 Framework and Weighting of Factors in the MTCA Disproportionate Cost Analysis

| Evaluation Criterion and WAC Citation | Benefit Weighting Percentages and Rationale | Rating Metrics Used |
|---|---|---|
| Protectiveness:<br>WAC 173-340-360(3)(f)(i) | **25%:** Protectiveness has a high weighting because it represents the ultimate goal of the cleanup. | • Cumulative exposure risk<br>• Cumulative benthic exposure risk<br>• Risks from implementation |
| Permanence<br>WAC 173-340-360(3)(f)(ii) | **20%:** Permanence receives a relatively high weighting value because it addresses the degree to which the remedial alternatives reduce exposure potential in the LDW. | • Reduction in volume of contaminated sediment<br>• Reduction in mobility of hazardous substances |
| Effectiveness over the long term:<br>WAC 173-340-360(3)(f)(iv) | **30%:** This category receives a relatively high weighting value because it addresses how well the remedy reduces risks and whether controls are adequate to maintain protection against exposures to contamination left in place in the long term. | • Degree of certainty that the remedial alternative will be successful<br>• Reliability of institutional and engineering controls used to manage risk |
| Management of short-term risk:<br>WAC 173-340-360(3)(f)(v) | **15%:** This category receives a relatively low weighting value because impacts to both human health and the environment are predictable and manageable. However, these risks are of significant magnitude for remedial alternatives that extend over long durations. | • Implementation risks<br>• Effectiveness of protective measures used to manage short-term risks |
| Technical and administrative implementability:<br>WAC 173-340-360(3)(f)(vi) | **5%:** This category receives a relatively low weighting value because it is not directly related to the goals of the environmental cleanup. Further, the alternatives are all considered to be implementable. | • Degree of technical complexity (access, size, availability of materials) and administrative (legal, regulatory, and monitoring) requirements; summarized as one metric |
| Consideration of Public Concerns:<br>WAC 173-340-360(3)(f)(vii) | **5%:** This weighting reflects the fact that the primary public concerns are generally embodied by the other 5 criteria. Public concern rankings provide a summary of the input from the public during public comment periods and public meetings for the FS. | • Estimate of the degree of public support for each alternative |
| Costs (see Appendix I):<br>WAC 173-340-360(3)(f)(iii) | This criterion is used to compare against the benefits for the disproportionate cost analysis. | • Net present value; see Appendix I |

Notes:

FS = Feasibility Study; LDW = Lower Duwamish Waterway; MTCA = Model Toxics Control Act; WAC = Washington Administrative Code

## Table 11-5 Summary of Disproportionate Cost Analysis – Alternative Benefits Scores

| | Evaluation Criteria | Remedial Alternatives and Scores[a] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2R | 2R–CAD | 3C | 3R | 4C | 4R | 5C | 5R | 5R– T | 6C | 6R |
| 1 | Protectiveness – total weighting factor: 25% | 4.0 | 4.0 | 5.2 | 5.0 | 5.9 | 5.2 | 7.0 | 5.2 | 5.2 | 7.5 | 4.2 |
| 2 | Permanence – total weighting factor: 20% | 2.4 | 1.9 | 2.6 | 3.1 | 3.7 | 4.6 | 4.4 | 6.1 | 6.1 | 5.9 | 9.5 |
| 3 | Effectiveness Over the Long Term – total weighting factor: 30% | 3.6 | 3.3 | 4.2 | 4.5 | 5.6 | 6.3 | 6.6 | 8.2 | 8.2 | 7.4 | 9.0 |
| 4 | Management of Short-term Risk – total weighting factor: 15% | 8.8 | 8.3 | 8.9 | 8.3 | 8.1 | 7.1 | 7.9 | 5.8 | 5.0 | 5.4 | 0.0 |
| 5 | Technical and Administrative Implementability – total weighting factor: 5% | 6.0 | 4.0 | 6.0 | 6.0 | 8.0 | 8.0 | 8.0 | 4.0 | 2.0 | 4.0 | 2.0 |
| 6 | Consideration of Public Concerns – total weighting factor: 5% | 1.0 | 0.0 | 5.0 | 3.0 | 5.0 | 5.0 | 7.0 | 7.0 | 7.0 | 7.0 | 8.0 |
| 7 | Total Weighted Benefits | 4.2 | 3.8 | 5.0 | 4.9 | 5.8 | 5.8 | 6.5 | 6.4 | 6.2 | 6.6 | 6.2 |
| 8 | Cost ($millions net present value) | 220 | 200 | 200 | 270 | 260 | 360 | 290 | 470 | 510 | 530 | 810 |
| 9 | Benefit/cost (Benefit points per $billion) | 19 | 19 | 25 | 18 | 22 | 16 | 22 | 14 | 12 | 12 | 7.7 |

Notes:

a. A score of 0 represents the lowest benefit or a poor performing alternative for the given metric. A score of 10 represents the highest benefit or an excellent performing alternative for the given metric. Scores of 0 and 10 do not represent the lowest and highest alternatives in the suite of alternatives, but represent the high and low values shown in the Benefit Scoring Basis columns on Table 11-6. The alternatives are scored on a linear scale between the end points shown in Table 11-6.

C = combined-technology; R = removal-emphasis; R-CAD = removal emphasis alternative with contained aquatic disposal; R-T = removal-emphasis alternative with treatment (soil washing)

**Table 11-6 Disproportionate Cost Analysis – Alternative Benefits Metrics and Scores**

| | Evaluation Criteria | | Weighting Factor | Benefit Scoring Basis[a] | | Units | Site-wide Remedial Alternatives | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Score 0 | Score 10 | | 2R | 2R-CAD | 3C | 3R | 4C | 4R | 5C | 5R | 5R-T | 6C | 6R |
| **1** | **Overall Protectiveness of Human Health and the Environment** | | **25%** | | | **Overall Score** | **4.0** | **4.0** | **5.2** | **5.0** | **5.9** | **5.2** | **7.0** | **5.2** | **5.2** | **7.5** | **4.2** |
| **1a** | Cumulative exposure | Concentration of total PCBs integrated over time. Assume total PCBs is a surrogate for all risk drivers.[b] | **50%** | 1,158 | 353 | (µg/kg dw) yrs | 1,035 | 1,035 | 950 | 950 | 863 | 903 | 768 | 898 | 898 | 595 | 808 |
| | Score 0 represents predicted exposure with natural recovery but without construction (i.e., Alt 1: 1,158 (µg/kg dw) yrs); score 10 represents no action at the start of construction, followed by the asymptote (39 µg/kg dw) from 5 to 45 years following initiation of construction (353 (µg/kg dw) yrs). | | | | | **Score** | **1.5** | **1.5** | **2.6** | **2.6** | **3.7** | **3.2** | **4.9** | **3.2** | **3.2** | **7.0** | **4.4** |
| **1b** | Cumulative benthic exposure | SQS exceedances integrated over time.[c] | **25%** | 2,055 | 560 | exceedance yrs | 1,465 | 1,465 | 1,090 | 1,090 | 900 | 975 | 560 | 830 | 830 | 560 | 830 |
| | Score 0 represents predicted exposure with natural recovery but without construction (i.e., Alt 1: 2,055 exceedance-yrs); score 10 represents no action at the start of construction, followed by no exceedances from 5 to 30 years following initiation of construction (585 exceedance-yrs). | | | | | **Score** | **3.9** | **3.9** | **6.5** | **6.5** | **7.7** | **7.2** | **10.0** | **8.2** | **8.2** | **10.0** | **8.2** |
| **1c** | Risks from implementation | Construction time. Assume that impacts during dredging are proportional to construction time when comparing remedial alternatives. | **25%** | 42 | 0 | yrs | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| | Score 0 represents construction time for Alt 6R (42 years); score 10 represents no additional construction after the EAAs (i.e., Alt 1: 0 yrs) | | | | | **Score** | **9.0** | **9.0** | **9.3** | **8.6** | **8.6** | **7.4** | **8.3** | **6.0** | **6.0** | **6.2** | **0.0** |
| **2** | **Permanence** | | **20%** | | | **Overall Score** | **2.4** | **1.9** | **2.6** | **3.1** | **3.7** | **4.6** | **4.4** | **6.1** | **6.1** | **5.9** | **9.5** |
| **2a** | Reduction in volume of contaminated sediment | Volume of sediment removed from LDW. Performance contingency volume minus volume contained by CAD for Alt 2R-CAD | **50%** | 0 | 3.90 | million cy | 0.58 | 0.27 | 0.49 | 0.76 | 0.69 | 1.20 | 0.75 | 1.60 | 1.60 | 1.60 | 3.90 |
| | Score 0 represents no volume removed after the EAAs (i.e., Alternative 1: 0 cy); score 10 represents the maximum amount of sediment removed for the remedial alternatives (i.e., Alt 6R: 3.9 million cy). | | | | | **Score** | **1.5** | **0.7** | **1.3** | **1.9** | **1.8** | **3.1** | **1.9** | **4.1** | **4.1** | **4.1** | **10.0** |
| **2b** | Reduction in mobility of hazardous substances | Immobility rating based on the acres weighted by type of technology applied in AOPC 1 normalized to acres in AOPC 1. | **50%** | Weighted average based on the following: | | | | | | | | | | | | | |
| | | dredge | | weighting: 9 | | acres of AOPC 1 | 29 | 5 | 29 | 50 | 50 | 93 | 57 | 143 | 143 | 69 | 164 |
| | | cap/partial dredge and cap (Alternative 2R–CAD includes 24 acres of CAD; acreage subtracted from the dredge area) | | weighting: 8 | | acres of AOPC 1 | 3 | 27 | 19 | 8 | 41 | 14 | 47 | 14 | 14 | 61 | 16 |
| | | *in situ* treatment | | weighting: 7 | | acres of AOPC 1 | 0 | 0 | 5.0 | 0 | 8 | 0 | 26.5 | 0 | 0 | 25.0 | 0 |
| | | ENR | | weighting: 4 | | acres of AOPC 1 | 0 | 0 | 5.0 | 0 | 8 | 0 | 26.5 | 0 | 0 | 25.0 | 0 |
| | | MNR and VM | | weighting: 2 | | acres of AOPC 1 | 148 | 148 | 122 | 122 | 73 | 73 | 23 | 23 | 23 | 0 | 0 |
| | Weightings for each technology are based on best professional judgment. MNR and VM do not score a 0 because monitoring and contingency actions would mitigate mobility of contaminated sediment. Dredging does not score a 10 because some amount of contamination is lost during the dredging process. Therefore, 0 and 10 represent idealized alternatives in which sediments either are not remediated (0), or are removed completely from the LDW (10). | | | | | **Score** | **3.2** | **3.1** | **4.0** | **4.2** | **5.6** | **6.1** | **6.8** | **8.0** | **8.0** | **7.7** | **8.9** |

**Table 11-6 Disproportionate Cost Analysis – Alternative Benefits Metrics and Scores (continued)**

| | Evaluation Criteria | | Weighting Factor | Benefit Scoring Basis[a] Score 0 | Score 10 | Units | 2R | 2R-CAD | 3C | 3R | 4C | 4R | 5C | 5R | 5R-T | 6C | 6R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | **Effectiveness Over the Long Term** | | **30%** | | | **Overall Score** | **3.6** | **3.3** | **4.2** | **4.5** | **5.6** | **6.3** | **6.6** | **8.2** | **8.2** | **7.4** | **9.0** |
| 3a | Degree of certainty that the remedial alternative will be successful | Degree of certainty rating based on weighted benefit of remedial technologies normalized to acres of AOPC 1. | **80%** | Weighted average based on the following: | | | | | | | | | | | | | |
| | | dredge | | | weighting: 9 | acres of AOPC 1 | 29 | 5 | 29 | 50 | 50 | 93 | 57 | 143 | 143 | 69 | 164 |
| | | cap/partial dredge and cap (Alternative 2R–CAD includes 24 acres of CAD; acreage subtracted from the dredge area) | | | weighting: 9 | acres of AOPC 1 | 3 | 27 | 19 | 8 | 41 | 14 | 47 | 14 | 14 | 61 | 16 |
| | | *in situ* treatment | | | weighting: 7 | acres of AOPC 1 | 0.0 | 0.0 | 5.0 | 0.0 | 8.0 | 0.0 | 26.5 | 0.0 | 0.0 | 25.0 | 0.0 |
| | | ENR | | | weighting: 6 | acres of AOPC 1 | 0.0 | 0.0 | 5.0 | 0.0 | 8.0 | 0.0 | 26.5 | 0.0 | 0.0 | 25.0 | 0.0 |
| | | MNR and VM | | | weighting: 3 | acres of AOPC 1 | 148 | 148 | 122 | 122 | 73 | 73 | 23 | 23 | 23 | 0 | 0 |
| | Weightings for each technology are based on best professional judgment. MNR and VM do not score a 0 because monitoring and contingency actions would mitigate mobility of contaminated sediment. Dredging does not score a 10 because some amount of contamination is lost during the dredging process. Therefore, 0 and 10 represent idealized alternatives in which sediments either are not remediated (0), or are removed completely from the LDW (10). | | | | | **Score** | **4.1** | **4.1** | **4.8** | **4.9** | **6.3** | **6.6** | **7.5** | **8.2** | **8.2** | **8.3** | **9.0** |
| 3b | Reliability of ICs and engineering controls used to manage risk | Score inversely proportional to total acres of caps, ENR, MNR, and VM in AOPC 1 (EAAs not included). Assume reliability of ICs and engineering controls is inversely proportional to the area of technologies that leave contamination on site. | **20%** | 180.0 | 0.0 | acres of AOPC 1 | 151 | 175 | 151 | 130 | 130 | 87 | 123 | 37 | 37 | 111 | 16 |
| | Score of 0 represents capping, ENR/*in situ*, MNR, or VM all of AOPC 1; score of 10 represents dredging all of AOPC 1. | | | | | **Score** | **1.6** | **0.3** | **1.6** | **2.8** | **2.8** | **5.2** | **3.2** | **7.9** | **7.9** | **3.8** | **9.1** |
| 4 | **Management of Short-term Risks** | | **15%** | | | **Overall Score** | **8.8** | **8.3** | **8.9** | **8.3** | **8.1** | **7.1** | **7.9** | **5.8** | **5.0** | **5.4** | **0.0** |
| 4a | Implementation risks[d] | Assume risk is proportional to removal and handling volume; equals dredge volume plus placement volume (including capping, ENR, backfill, dredge residuals management, and CAD construction). Assume double handling for Alt 5R-T for half of sediment removed for treatment. | **50%** | 5.1 | 0 | million cy | 0.71 | 1.2 | 0.76 | 1.0 | 1.2 | 1.6 | 1.3 | 2.2 | 3.0 | 2.8 | 5.1 |
| | Score of 0 represents maximum amount of material handled out of the remedial alternatives (i.e., Alt 6R; 5.1 million cy); score 10 represents no material handled (i.e., Alt 1) | | | | | **Score** | **8.6** | **7.6** | **8.5** | **8.0** | **7.6** | **6.9** | **7.5** | **5.7** | **4.1** | **4.5** | **0.0** |
| 4b | Effectiveness of protective measures to manage short-term risks | Assume that impacts during dredging are proportional to construction time. | **50%** | 42 | 0 | years | 4.0 | 4.0 | 3.0 | 6.0 | 6.0 | 11.0 | 7.0 | 17.0 | 17.0 | 16.0 | 42.0 |
| | Score 0 represents construction time for Alt 6R (42 yrs); score 10 represents no additional construction after the EAAs (i.e., Alt 1; 0 yrs) | | | | | **Score** | **9.0** | **9.0** | **9.3** | **8.6** | **8.6** | **7.4** | **8.3** | **6.0** | **6.0** | **6.2** | **0.0** |
| 5 | **Technical and Administrative Implementability** | | **5%** | | | **Overall Score** | **6.0** | **4.0** | **6.0** | **6.0** | **8.0** | **8.0** | **8.0** | **4.0** | **2.0** | **4.0** | **2.0** |
| | Best professional judgment based on experience with other remediation sites. Higher score represents more feasible and lower score represents less feasible. | | | | | | | | | | | | | | | | |
| 6 | **Consideration of Public Concerns** | | **5%** | | | **Overall Score** | **1.0** | **0.0** | **5.0** | **3.0** | **5.0** | **5.0** | **7.0** | **7.0** | **7.0** | **7.0** | **8.0** |
| | Best professional judgment based on meetings with the public. Higher score represents more public support and lower score represents less public support. | | | | | | | | | | | | | | | | |
| 7 | **Total Weighted Benefits** | | | | | **Score** | **4.2** | **3.8** | **5.0** | **4.9** | **5.8** | **5.8** | **6.5** | **6.4** | **6.2** | **6.6** | **6.2** |
| 8 | **Cost** | | | | | **$millions net present value - excluding EAAs** | **220** | **200** | **200** | **270** | **260** | **360** | **290** | **470** | **510** | **530** | **810** |

Notes:

a. A score of 0 represents the lowest benefit or a poor performing alternative for the given metric. A score of 10 represents the highest benefit or an excellent performing alternative for the given metric. Scores of 0 and 10 do not represent the lowest and highest alternatives in the suite of alternatives, but represent the high and low values shown in the Benefit Scoring Basis columns. The alternatives are scored on a linear scale between these end points.

b. Total PCB SWAC based on the best estimate (mid input values) BCM output. Cumulative exposure = (Average PCB concentration over 45 years - 39 µg/kg dw) x 45 years.

c. Cumulative benthic exposure = (Average number of SQS point exceedances over 30 years) x 30 years for representative SMS contaminants.

d. Implementation risks include release of residual contamination into the water column during dredging, landfill usage, environmental impacts due to transportation of material and mining of sand, worker safety, greenhouse gas emissions, particulate emissions, and other factors. For the purpose of this metric, the volume of material handled is used as a surrogate for these risks.

Alt = alternative; AOPC = area of potential concern; BCM = bed composition model; BPJ = best professional judgment; C = combined technology; CAD = contained aquatic disposal; cy = cubic yards; EAA = early action area; ENR = enhanced natural recovery; ICs = institutional controls; MNR = monitored natural recovery; MTCA = Model Toxics Control Act; PDC = partial dredge and cap; R = removal focused; RAO = remedial action objective; R-CAD = removal-emphasis alternative with contained aquatic disposal; R–T = removal-emphasis alternative with treatment (soil washing); SQS = sediment quality standard; SWAC = spatially-weighted average concentration; VM = verification monitoring

## Table 11-7 Estimated Additional Costs for Soil Washing for All Remedial Alternatives

| Remedial Alternative | Baseline Estimated Cost ($million net present value) | Removal Volume (million cy) | Estimated Additional Cost for Treatment with Beneficial Reuse[a] ($million net present value) | Estimated Additional Cost for Treatment without Beneficial Reuse[b] ($million net present value) |
|---|---|---|---|---|
| 1 | 9[c] | n/a | n/a | n/a |
| 2R | 220 | 0.58 | 29 | 57 |
| 2R-CAD | 200 | 0.58 | n/a | n/a |
| 3C | 200 | 0.49 | 25 | 51 |
| 3R | 270 | 0.76 | 30 | 66 |
| 4C | 260 | 0.69 | 28 | 60 |
| 4R | 360 | 1.2 | 40 | 88 |
| 5C | 290 | 0.75 | 30 | 64 |
| 5R | 470 | 1.6 | 45 | 102 |
| 5R-T | 510 | 1.6 | n/a | 58 |
| 6C | 530 | 1.6 | 48 | 109 |
| 6R | 810 | 3.9 | 76 | 180 |

Notes:

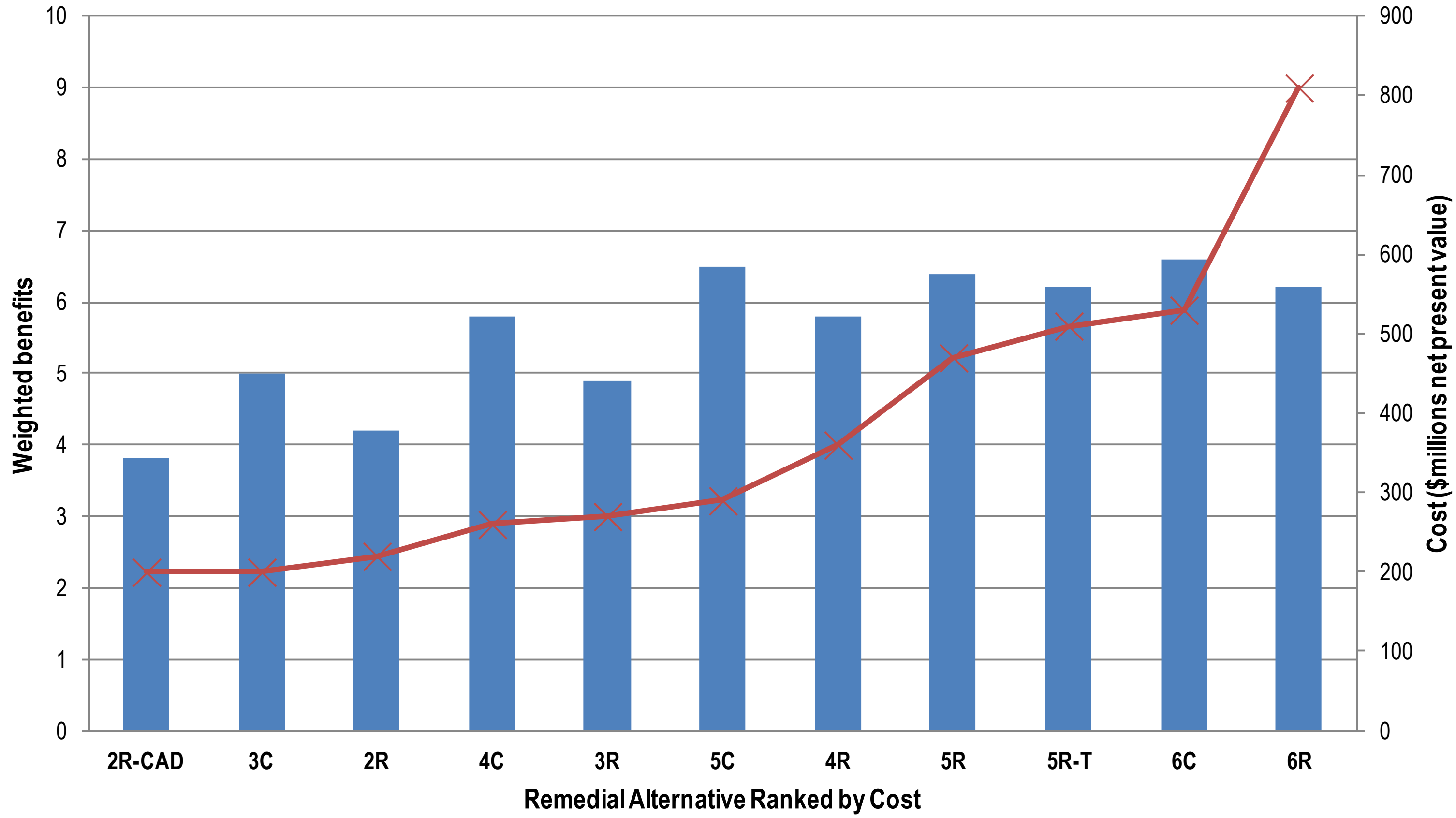
a. Cost for treatment with beneficial reuse assumes the cost for mobilization, soil washing treatment operations including water management, upland disposal of fine fraction of treated sediment, and reuse of sand fraction at no cost. 50% of dredged sediment is assumed to be viable for soil washing.

b. Cost for treatment without beneficial reuse assumes the cost for mobilization, soil washing treatment operations including water management, and upland disposal of both fine fraction and sand fraction of treated sediment. 50% of dredged sediment is assumed to be viable for soil washing.

c. Alternative 1 costs ($9 million) are for LDW-wide monitoring, agency oversight, and reporting and do not include operation and maintenance. The cost of cleanup actions in the EAAs is estimated at approximately $95 million. The EAA cleanup action costs are provided for informational purposes and are not used in the comparison of alternatives.

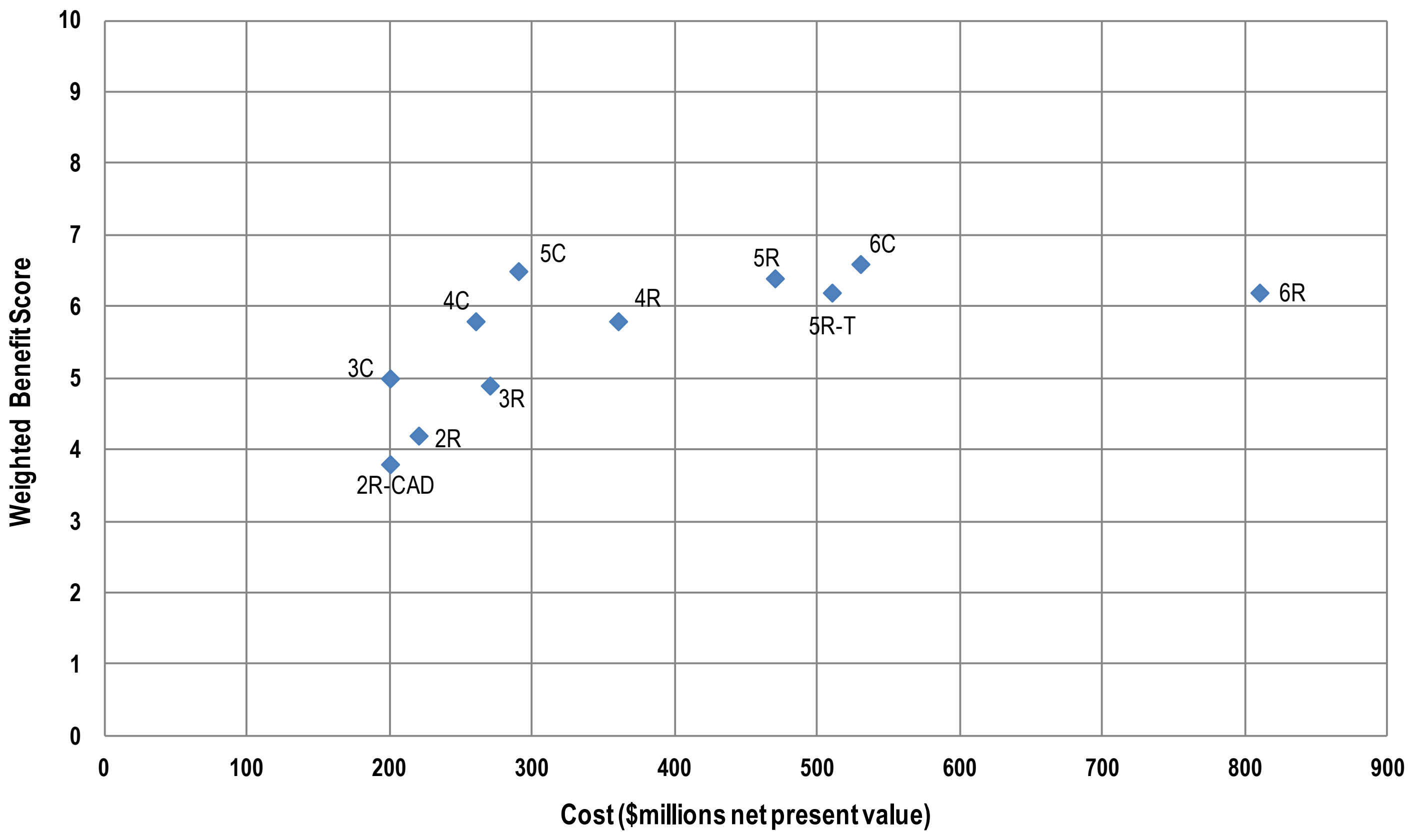
C = combined-technology alternative; cy = cubic yard; EAA = early action area; n/a = not applicable; LDW = Lower Duwamish Waterway;
R = removal-emphasis alternative. R-CAD = removal alternative with contained aquatic disposal; R-T = removal alternative with treatment

**Figure 11-1 Benefits and Costs for Remedial Alternatives (Ranked by Cost)**




Notes:
C = combined-technology alternatives
R = removal-emphasis alternatives with upland disposal
R-CAD = removal-emphasis alternative with contained aquatic disposal
R-T = removal-emphasis alternative with soil washing treatment

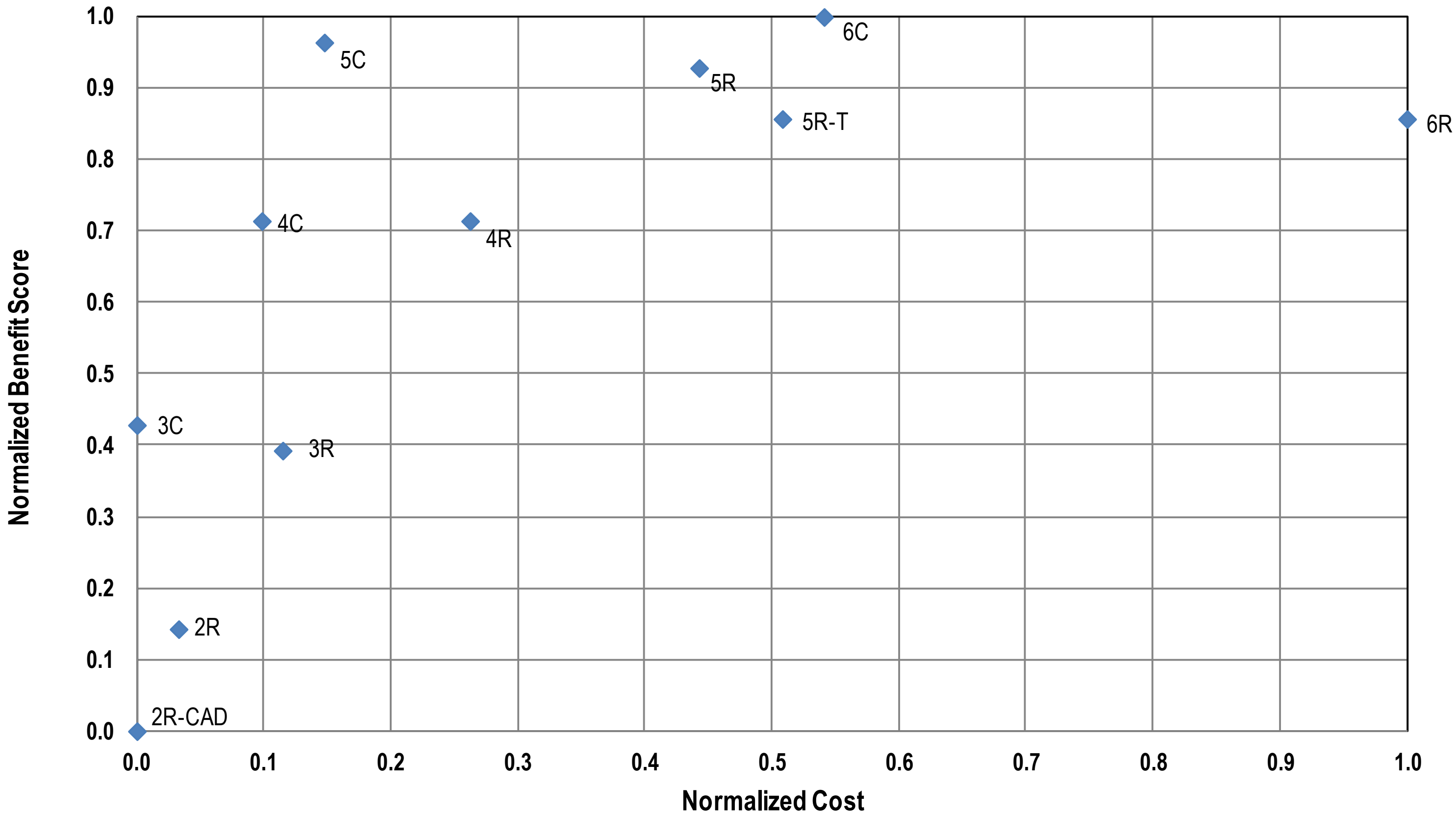
**Figure 11-2 Benefits vs. Costs for Remedial Alternatives**




Notes:

C = combined-technology alternative; R = removal-emphasis alternatives with upland disposal; R-CAD = removal-emphasis alternative with contained aquatic disposal; R-T = removal-emphasis alternative with soil washing treatment.

## Figure 11-3 Normalized Benefits vs. Normalized Costs for Remedial Alternatives




Notes:

1. Costs and benefits were normalized as the difference between the value for an alternative and the minimum value of the alternatives divided by the range in values for all the alternatives.

Normalized value = ((value)-(min alt))/((max alt)-(min alt))

C = combined-technology alternatives; R = removal-emphasis alternatives with upland disposal; R-CAD = removal-emphasis alternative with contained aquatic disposal; R-T = removal-emphasis alternative with soil washing treatment

# 12 Conclusions

Cleanup of the Lower Duwamish Waterway (LDW) is a complex, large-scale undertaking that seeks to accomplish important human health and environmental objectives in a challenging urban/industrial setting. This feasibility study (FS) evaluated several factors to develop and compare a full range of remedial alternatives for the LDW that are protective over the long term. These factors include estimating the deposition of new sediments from upstream and their associated contaminant concentrations, forecasting the timing and future results of upland source control in numerous locations along the LDW, estimating dredge volumes and costs, estimating post-remediation surface contaminant concentrations and the uncertainties around those values, and predicting the time needed to implement cleanup and achieve cleanup objectives. However, uncertainties exist for each of these factors.

The National Research Council (NRC) published a report in 2007 on sediment cleanups at large Superfund sites that identifies similar challenges elsewhere in the country, and suggests how to move forward in selecting remedies for sites as large and complex as the LDW. The report concludes with the following excerpt:

> *If there is one fact on which all would agree, it is that the selection and implementation of remedies at contaminated sediment sites are complicated. Many large and complex contaminated sediment sites will take years or even decades to remediate and the technical challenges and uncertainties of remediating aquatic environments are a major obstacle to cost-effective cleanup.*
>
> *Because of site-specific conditions – including hydrodynamic setting, bathymetry, bottom structure, distribution of contaminant concentrations and types, geographic scale, and remediation time frames – the remediation of contaminated sediment is neither simple nor quick, and the notion of a straightforward "remedial pipeline" that is typically used to describe the decision-making process for Superfund sites is likely to be at best not useful and at worst counterproductive.*
>
> *The typical Superfund remedy-selection approach, in which site studies in the remedial investigation and feasibility study establish a single path to remediation in the record of decision, is not the best approach to remedy selection and implementation at these sites owing to the inherent uncertainties in remedy effectiveness. At the largest sites, the time frames and scales are in many ways unprecedented. Given that remedies are estimated to take years or decades to implement and even longer to achieve cleanup goals, there is the potential – indeed almost a certainty – that there will be a need for changes, whether in response to new knowledge about site conditions, to changes in site conditions from extreme storms or flooding, or to advances in technology (such as improved dredge or cap design or in situ treatments). Regulators and others will need to adapt continually to evolving conditions and environmental responses that cannot be foreseen.*
>
> *These possibilities reiterate the importance of phased, adaptive approaches for sediment management at megasites. As described previously, adaptive management*

> *does not postpone action, but rather supports action in the face of limited scientific knowledge and the complexities and unpredictable behavior of large ecosystems.*

In that context, this section discusses:

- Key conclusions related to protecting human health and the environment by comparing the remedial alternatives with respect to their compliance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Model Toxics Control Act (MTCA) criteria
- A comparison of the analysis in this FS to the most recent national guidance regarding remedy selection for contaminated sediment sites
- Uncertainties identified and addressed in the LDW.

Similarities and differences among the alternatives and how they compare under CERCLA and MTCA are described in Section 12.1, along with the key findings. Risk management principles and national guidance are discussed next in Section 12.2. Section 12.3 briefly describes the uncertainties associated with the alternatives and their predicted outcomes. The final section, 12.4, discusses the next steps in the process for selecting the remedy for the LDW in coordination with other LDW cleanup activities.

## 12.1 Summary of the Comparative Analysis under CERCLA and MTCA

Twelve alternatives were individually evaluated against the CERCLA criteria in Section 9, compared to each other in Section 10, and evaluated against the MTCA criteria in Section 11, including a disproportionate cost analysis (DCA). CERCLA provides a set of prescribed criteria against which the remedial alternatives are evaluated (Table 9-1). MTCA has a similar framework for evaluating alternatives, with a few important distinctions (Tables 11-1 and 11-2) that have been incorporated into the following discussions.

Table 12-1 summarizes each alternative's remedial technologies, the size of the active remedial footprint, the volumes and costs, the time frame predicted for achieving the cleanup objectives, and residual risks (predicted outcomes). Differences in overall protectiveness of Alternatives 2 through 6 are largely in the context of short-term and long-term effectiveness. The lower numbered/smaller alternatives rely more on a passive remediation technology (monitored natural recovery [MNR]) to achieve cleanup objectives, while higher numbered/larger alternatives rely more on active remediation technologies such as dredging, capping, enhanced natural recovery (ENR), and ENR with *in situ* treatment (ENR/*in situ*). The major differences among the alternatives with the same remedial action levels (RALs) are the reliance on dredging for the active portion of the removal-emphasis alternatives versus a combination of dredging, capping, and ENR/*in situ* for the active portion of the combined-technology alternatives.

Figure 12-1 presents a summary of the comparative analysis under the CERCLA evaluation criteria. Alternative 1 failed to meet CERCLA threshold criteria but was retained for comparative purposes as the No Action Alternative. A high ranking (full red dot) means that the alternative ranks relatively high compared to other alternatives, whereas a low ranking (full black dot) means the alternative ranks low compared to other alternatives. In many cases, the evaluation did not identify substantial differences among the alternatives and therefore the rankings are the same for those criteria.

Figure 12-2 presents a summary of the comparative analysis under the MTCA evaluation criteria. Overall, the MTCA analysis yielded results similar to the CERCLA analysis. However, MTCA has specific differences in the factors that were considered under each evaluation criterion, and unlike CERCLA, MTCA adds the DCA to screen out alternatives with disproportionately higher costs. For DCA purposes only, the metrics used in the comparative analysis are converted to numerical scores. These scores are combined for a total weighted benefit score. Based on the MTCA analysis, Alternatives 5C, 5R, and 6C have the highest weighted benefit scores among the alternatives (Figure 12-2). Alternatives 4C, 4R, 5R-Treatment, and 6R have lower weighted benefit scores, and Alternatives 2R and 2R-CAD (contained aquatic disposal) have the lowest scores (see Figure 12-2). The total benefit scores are then considered relative to the cost of each alternative as a means of comparing the benefit of each alternative relative to its cost (i.e., the DCA) (see Figure 12-2). The analysis indicates that the additional costs incurred for alternatives beyond Alternative 5C do not add appreciably greater benefits.

The following sections summarize the key points of the comparative analyses and the performance of the remedial alternatives related to both the CERCLA and MTCA requirements. The following discussion is organized by the nine CERCLA criteria (two threshold criteria, five balancing criteria, and two modifying criteria). The last two modifying criteria, state/tribal and community acceptance, are discussed in Section 12.2.

### 12.1.1 Overall Protection of Human Health and the Environment

Predictions of whether remedial alternatives achieve cleanup objectives[1] and of the risks to remain after cleanup and natural recovery are summarized below for each alternative:

- Alternatives 1 through 6 are predicted to achieve similar levels of excess cancer risks for total polychlorinated biphenyls (PCBs). The risk levels are in the range of 1 in 10,000 ($10^{-4}$ magnitude risk), depending on the seafood consumption reasonable maximum exposure (RME) scenario (Adult Tribal, Child Tribal, and Asian Pacific Islander, see Section 9.3.3). The outcomes are

[1] Cleanup objective in this FS is used to mean the PRG or as close as practicable to the PRG, when the PRG is predicted to not be achievable.

presented in Table 12-1 and Figure 12-3. However, each alternative varies in: 1) the technologies used to reduce risk, 2) how quickly contaminant concentrations are reduced, and 3) the uncertainty associated with the long-term model-predicted concentrations, as discussed below. None of the alternatives reach the MTCA threshold risk of 1 × 1,000,000 ($1 \times 10^{-6}$) for individual contaminants for the three seafood consumption RME scenarios. Non-cancer hazard quotients for total PCBs are predicted to range from 3 to 10 for all alternatives for the three seafood consumption RME scenarios, with no alternative achieving non-cancer hazard quotients of less than 1. Alternatives 1 through 5 rely to varying degrees on natural recovery to achieve these results, and the degree of model uncertainty decreases in alternatives with less passive remediation.

- None of the alternatives are predicted to achieve the total PCB and dioxin/furan preliminary remediation goals (PRGs) in sediment for the human seafood consumption scenarios (remedial action objective [RAO] 1), which are based on natural background concentrations.[2] Instead, for Alternatives 2 through 6, the cleanup objective is achieved when total PCB and dioxin/furan concentrations are as close to natural background as technically practicable. The long-term model-predicted concentrations are used in this FS to approximate these values. They are also used to estimate the time required to achieve these cleanup objectives (Table 12-1). Seafood consumption advisories are expected to remain in effect in the LDW, no matter which alternative is selected.
- While it was not possible to reliably establish arsenic and carcinogenic polycyclic aromatic hydrocarbon (cPAH) PRGs for sediment for the seafood consumption exposure pathway (RAO 1), Alternatives 1 through 6 all reduce surface sediment concentrations of these risk drivers to similar long-term model-predicted concentrations over time.
- Alternatives 3 through 6 actively remediate areas to reduce surface sediment contaminant concentrations to levels that protect humans from adverse effects associated with direct contact with sediment (RAO 2). In all cases, active remediation alone reduces total excess cancer risks from all four risk drivers under all direct contact exposure scenarios (netfishing, clamming, and beach play areas) to no higher than 1 in 100,000 ($1 \times 10^{-5}$) and reduces non-cancer hazard quotients to less than or equal to 1. Total excess cancer risk for total PCBs, dioxins/furans, and cPAHs are reduced to 1 in 1,000,000 ($1 \times 10^{-6}$) or below. However, the individual excess cancer risk posed by arsenic is greater than $1 \times 10^{-6}$ because the natural background concentration of arsenic yields risks above that level. The arsenic PRG for sediment for all

[2] There are no RAO 1 PRGs for cPAHs and arsenic. See Section 4.4 for details.

direct contact scenarios is set to natural background, which is not technically practicable to achieve. Therefore, the cleanup objective, in this case, is as close to natural background as is technically practicable, estimated in this FS using the long-term model predicted concentration. This concentration is approximately the same for all alternatives. Alternatives 1 and 2 rely on natural recovery to achieve the same risk reductions; model predictions for these alternatives suggest that levels of performance similar to the other alternatives can be achieved over time.

- Alternatives 1 through 6 are predicted to achieve RAO 3 PRGs (the sediment quality standards [SQS] of the Washington State Sediment Management Standards [SMS]) for protection of the benthic community. Alternatives 3 through 6 are predicted to achieve RAO 3 PRGs in 6 to 11 years, but the predicted times to achieve RAO 3 PRGs for Alternatives 1 and 2 are much longer (20 and 14 years, respectively). Alternatives 1 through 4 are predicted to need progressively less natural recovery to achieve the SQS following active remediation.

- Alternatives 2 through 6 are predicted to protect wildlife (RAO 4) by actively reducing total PCB concentrations below levels that correspond to a hazard quotient of less than 1 for wildlife that consume resident seafood. Alternative 1 is predicted to achieve the RAO 4 PRG through natural recovery within 5 years or less following completion of the early action areas (EAAs). Alternatives 2 through 6 are predicted to achieve the RAO 4 PRG immediately following construction. Resident fish and shellfish tissue contaminant concentrations are assumed to remain elevated during construction as a result of contaminants released during dredging that enter the food chain.

Alternatives that emphasize dredging leave less contaminated subsurface sediment in place after active remediation[3] is complete. Therefore, disturbance mechanisms (such as vessel scour and earthquake-induced displacements) have less potential to expose subsurface contamination in the future. However, alternatives that rely more on dredging have higher short-term impacts to human health and the environment and they are likely to maintain elevated seafood tissue contaminant concentrations over the duration of construction and for some time thereafter. Construction times are longer for dredging than for other active remediation technologies over a similar area.

Alternatives 2 through 6 meet the threshold criterion for overall protection of human health and the environment through the use of varying combinations of active cleanup, natural recovery, and institutional controls. While Alternative 1, the No Further Action Alternative, is predicted to achieve the cleanup objectives for RAOs 1,

[3] The period of active remediation corresponds to the construction period.

2, 3, and 4 with natural recovery (over a lengthy period of time for all, except RAO 4), it does not provide for institutional controls other than the existing Washington State Department of Health (WDOH) seafood consumption advisory and institutional controls developed specifically for the EAAs. Therefore, this alternative does not satisfy this threshold criterion. However, it is retained for comparative purposes. Long-term risk reduction estimates are based primarily on the model predictions of spatially-weighted average concentrations (SWACs) in surface sediment. Uncertainties associated with SWAC predictions are discussed in Section 9.3.5.

### 12.1.2 Compliance with ARARs

Because this FS is being conducted under a joint CERCLA and MTCA order, provisions of MTCA and the SMS are considered to be applicable or relevant and appropriate requirements (ARARs) under CERCLA and governing requirements under MTCA/SMS.

- None of the alternatives satisfy the threshold requirement of complying with ARARs, particularly the excess cancer risk standards in MTCA for RAO 1, as described in Section 12.1.1, or MTCA's default to natural background concentrations for final remedies where risk-based threshold concentrations (RBTCs) are more stringent than background. Specifically, human health RBTCs (total PCBs and dioxins/furans for seafood consumption [RAO 1] and arsenic for direct contact [RAO 2]) are lower than natural background concentrations, and none of the alternatives are predicted to achieve natural background sediment concentrations for these contaminants of concern.
- Alternative 1 also does not comply with other MTCA ARARs, including institutional control requirements in WAC 173-340-440.
- It is not anticipated that any alternative will comply with all federal or state ambient water quality criteria or standards, particularly those based on human consumption of bioaccumulative contaminants that magnify through the food chain, such as PCBs, because upstream concentrations (which could change over time) currently exceed those criteria or standards. However, significant water quality improvements are anticipated from sediment remediation and source control. Water quality is likely to be variable throughout the LDW, depending on the extent of local sources. Generally, the more quickly and thoroughly contaminated sediments are remediated and sources are controlled, the more quickly water quality improvements should occur.

ARAR waivers could be issued by the U.S. Environmental Protection Agency (EPA) in the future for those contaminants of concern and exposure scenarios that do not meet natural background-based PRGs, MTCA risk thresholds, or water quality criteria or standards. CERCLA requires that all ARARs be met or waived at or before completion of the remedial action. By far the most common waiver is for technical impracticability. In instances where alternatives are not predicted to comply with ARARs, the goal is to get as close as technically practicable to the ARAR, and apply a waiver only to the extent necessary. Because future conditions are difficult to predict, actual data collected upon completion of the remedial action will underlie the basis for any such waivers, which are formally documented and issued by EPA. For this reason, more definitive statements on whether, and perhaps more significantly to what extent, ARARs will be achieved or potentially waived cannot be made at this time, but must be made at the completion of cleanup and source control work at the site.

### 12.1.3 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence considers the relative magnitude and type of residual risks that would remain in the LDW after the cleanup objectives have been achieved. It also assesses the extent and effectiveness of the controls that may be required to manage these residual risks. The comparative analysis found:

- Post-remediation residual surface sediment contaminant concentrations and the associated risks are predicted to be similar among the alternatives based on long-term model-predicted outcomes. Active remediation alone (i.e., ignoring any contribution from natural recovery) is responsible for the majority of progress toward achieving the residual risk levels for all alternatives. However, Alternatives 1, 2, 3, and 4 rely more on natural recovery and thus have greater degrees of uncertainty in the predicted outcomes.

- An approximately 50 to 90% reduction over time in site-wide surface sediment concentrations for risk drivers is predicted for all alternatives compared to baseline conditions; about 50% of the reduction in the total PCB SWAC is predicted to result from cleanup of the EAAs (see Figure 12-3 for total PCBs; see Figures 10-1b through 10-1d for the other three risk drivers).

- Differences in the level of effort and reliability of control mechanisms to manage residual risks, once cleanup objectives are achieved, are related primarily to the areal extent of remaining subsurface contamination. The remedial alternatives differ in the amount of contaminated subsurface sediment remaining with concentrations above levels needed to achieve cleanup objectives, which, if exposed or brought to the surface, could pose human health or ecological risks (see Table 10-1 for metrics). Alternatives that dredge across a greater surface area, in particular the higher numbered and removal-emphasis alternatives, remove more subsurface contaminated sediments from the LDW over a larger area, and thus have a lower potential for subsurface sediment to be exposed compared to the lower numbered and combined-technology alternatives. Similarly, more capped surface area translates into lower risk from subsurface sediments than areas addressed by ENR/*in situ* or MNR because caps are engineered to remain structurally stable under location-specific conditions.

- Alternatives 2 through 6 require monitoring, maintenance, and institutional controls in varying degrees or durations, with periodic reviews (e.g., every 5 years) and contingency actions, as needed. In general, combined-technology alternatives and lower numbered alternatives have greater monitoring and maintenance requirements, because they leave a greater amount of contaminated subsurface sediment in place. Alternative 1 provides for site-wide monitoring as a supplement to monitoring plans developed for the EAAs. Alternative 1 provides for no institutional controls beyond those developed for the EAAs and the existing WDOH seafood consumption advisory. Alternative 1 also does not provide for contingency actions. Alternatives 2 through 6 have public education and outreach programs in addition to the WDOH seafood consumption advisory to increase seafood consumers' awareness of risks and to reduce unacceptable exposures. However, the extent to which human exposure to contaminants in resident fish and shellfish can be reduced through seafood consumption advisories, public education, and outreach programs is unknown. Outreach and notification to waterway users, review of USACE construction permit applications, and environmental covenants or similar controls to avoid disturbance of subsurface contamination will be required to varying degrees depending on the remedial alternative.

Uncertainty related to long-term effectiveness and permanence is discussed in Section 10.2.1.3. Uncertainty associated with residual risks from exposure to surface sediment is largely influenced by the quality of incoming sediment from the Green/Duwamish River, the amount of contaminant inputs from lateral sources, and the potential for future anthropogenic or natural disturbances to expose subsurface contamination. Source control is clearly an important factor in reducing the long-term contaminant concentrations to the maximum extent practicable. Processes that can disturb sediment (e.g., earthquakes, vessel scour under high power operations) have the potential to expose contaminated subsurface sediment left in place following remedial actions. Ongoing disturbances that expose contamination at depth may increase long-term surface sediment contaminant concentrations, depending on the amount of subsurface contamination left in place, the extent of disturbance, and the sedimentation rate at the disturbance locations (see Section 9.1.2.1 and Appendix M, Part 5). Some disturbances (e.g., from maneuvering of vessels) may be small and difficult to detect. This uncertainty may be partially managed by refining the monitoring plan during remedial design.

Alternatives 1 through 6 progressively rank from low to high for long-term effectiveness and permanence, and the combined-technology alternatives rank lower than the removal-emphasis alternatives. Key differences in the rankings are based on the amount of contaminated sediment removed or managed in place and the degree to which institutional controls and monitoring are needed to manage the remaining material.

### 12.1.4 Reductions in Mobility, Toxicity, or Volume through Treatment

Section 121(b) of CERCLA establishes a preference for the selection of remedial action "which permanently and significantly reduces the volume, toxicity, or mobility of contaminants through treatment as a principal element." This statutory preference is the basis for this balancing criterion. Section 300.430 (a)(1)(iii) of the National Contingency Plan (2007) sets forth the expectation that treatment will be used for principal threat wastes (e.g., liquids, high concentrations of toxic compounds, and highly mobile materials) wherever practicable. Most of the contaminated sediments within the LDW are low-level threat wastes (Section 9.1.2.2). The FS evaluation of reduction of mobility, toxicity, or volume through treatment had these key results:

- Alternative 5R-Treatment is the only alternative that includes an *ex situ* treatment technology (soil washing). Soil washing could decrease the volume of dredged sediment requiring upland disposal but not the mass of contaminants. Alternative 5R-Treatment ranks the highest among the alternatives for this criterion because the volume of contaminated sediment requiring disposal may be reduced.

- Although not included in the FS evaluation of alternatives, other alternatives could include treatment of material after dredging; FS-level unit costs for the addition of *ex situ* treatment (soil washing) to each alternative are shown in Table 11-7.

- *In situ* treatment, using activated carbon or other sequestering agents, was included in all of the combined-technology alternatives. This treatment lowers contaminant mobility and hence contaminant toxicity and availability to biological receptors (i.e., bioavailability). The reduction of mobility achieved by *in situ* treatment was assumed to be proportional to the area where treatment is applied (50% of the ENR footprint). Alternatives 5C and 6C were ranked higher (with 26.5 and 50.5 acres, respectively, of potential *in situ* treatment) compared to Alternatives 3C and 4C (with 5 and 8 acres, respectively, of potential *in situ* treatment). The removal-emphasis alternative counterparts (except for 5R-Treatment, as noted above) ranked the lowest for this criterion.

- All of the alternatives make use of one or more of the following technologies: removal, disposal, containment, ENR, and natural recovery. Although none of these are treatment technologies under CERCLA, removal and off-site disposal do reduce the toxicity, mobility, and volume of contaminants remaining in the LDW compared to Alternative 1, and other technologies, notably engineered capping (and, to a lesser extent, ENR/*in situ*), also reduce the mobility and toxicity of contaminants.

### 12.1.5 Short-term Effectiveness

Short-term effectiveness is a measure of the time required to achieve the cleanup objectives, the risks and impacts to the community and environment that may occur during that time, and the effectiveness and reliability of measures to reduce these impacts. This FS evaluates risks and impacts to the community and environment, which may be elevated for many years until the cleanup objectives are achieved (both during construction and any needed period of natural recovery following construction). The FS evaluation of short-term effectiveness had these key results:

- Alternatives with longer construction times and greater dredge volumes present proportionately larger risks to workers, the community, and the environment, and therefore generally rank lower for these short-term effectiveness factors. Although best management practices will be used to reduce impacts to the extent practicable, longer construction periods increase equipment and vehicle emissions, noise, and other resource uses. Larger actively remediated footprints increase the short-term disturbance of the existing benthic community and other resident aquatic life and generate greater releases of bioavailable contaminants into the water column over a longer period of time. This keeps resident fish and shellfish tissue contaminant concentrations elevated during construction.

- No alternative is predicted to achieve the low RAO 1 PRGs of natural background for total PCBs and dioxins/furans (there are no RAO 1 PRGs for arsenic or cPAHs). Further, it cannot be known with certainty or precision what concentrations will ultimately be as close as practicable to these natural background PRGs (i.e., the cleanup objectives). Therefore, the long-term model-predicted concentration ranges of site-wide SWACs are the best available estimates and are used in this FS as the surrogate metric for achieving the cleanup objectives. Alternatives 1 through 5 require a period of natural recovery to reach the long-term model-predicted SWAC, ranging from 17 to 25 years (with Alternative 1 having the longest time frame) (Table 12-1). Alternative 6 is predicted to achieve the long-term model-predicted SWAC immediately after construction (16 years for Alternative 6C and 42 years for Alternative 6R).

- For RAO 2, all alternatives are predicted to achieve the cleanup objectives through engineering controls and varying degrees of natural recovery over periods of 3 to 25 years. Alternatives 3, 4, 5, and 6 achieve the RAO 2 cleanup objectives in the shortest times (varying between 3 and 6 years). Alternatives 1 and 2 require additional time for natural recovery after construction (25 and 19 years, respectively).

- For RAO 3, all alternatives are predicted to achieve the cleanup objectives (the SQS) through engineering controls and varying degrees of natural recovery over periods of 6 to 20 years. Alternatives 4C, 5C, and 6C are predicted to achieve the SQS in 6 years. Alternative 3C is predicted to achieve the SQS in 8 years. Alternatives 3R, 4R, 5R/5R-Treatment, and 6R are predicted to achieve the SQS in 11 years. Alternatives 2R/2R-CAD are predicted to achieve the SQS in 14 years. Alternative 1 is predicted to achieve the SQS through natural recovery processes in about 20 years after cleanup of the EAAs.
- For RAO 4, all alternatives are predicted to achieve the cleanup objective through engineering controls and varying degrees of natural recovery over periods of 3 to 42 years. Alternatives 1, 2, 3, 4C, and 5C have the shortest times (varying between 3 and 7 years), while Alternatives 4R, 5R/5R-Treatment, and 6 require longer times (varying between 11 and 42 years) to achieve the cleanup objective).
- When viewed collectively, Alternatives 5C and 6C are predicted to achieve cleanup objectives for all 4 RAOs, including the long-term model-predicted concentrations, in the shortest time frames (16 to 17 years).

Uncertainty related to short-term effectiveness is associated with several factors, including: 1) the model predictions for natural recovery, 2) duration of construction, and 3) sequencing of remedial actions (see Section 10.2.3.4). Natural recovery is a source of uncertainty influencing predictions of the time to achieve cleanup objectives. The bed composition model (BCM) does not account for disturbance of contaminated subsurface sediments except by high-flow scour; thus disturbances caused by other mechanisms (e.g., vessel scour) add to the uncertainty in time to achieve cleanup objectives, especially for alternatives that rely more on MNR.[4]

Alternatives 3C, 4C, and 5C are ranked relatively high compared to other alternatives for short-term effectiveness. Key differences in these rankings are based on the construction periods (shorter construction periods for active remediation have lower impacts) and the time to achieve cleanup objectives.

### 12.1.6 Implementability

This criterion considers both the technical and administrative ability to implement each alternative. Each alternative involves various combinations of technologies that have been successfully implemented at numerous sites in the Puget Sound region and throughout the country. The required equipment and appropriately skilled personnel

[4] While the FS assumes that contingency actions may be necessary to address unacceptable performance in some MNR and ENR areas, the time to complete those actions was not factored into the time to achieve cleanup objectives.

are readily available and coordination of the activities among agencies can be achieved. Based on the comparative analysis:

- Alternatives with shorter construction periods are easier to implement than those with longer construction periods. This reduces the overall level of difficulty both technically and administratively (e.g., coordination with agencies) and the potential for technical problems leading to schedule delays. In this context, Alternative 1 is the most implementable of the alternatives. The only long-term action undertaken for Alternative 1 is monitoring; no contingency actions are assumed to be undertaken outside the EAAs in response to monitoring data.
- Alternatives with more stringent (i.e., lower) RALs require more active remediation and are therefore more complex, have longer construction periods, and require more administrative coordination than do alternatives that have less stringent or higher RALs, less active remediation, and shorter construction periods. Similarly, removal-emphasis alternatives have longer construction periods and will likely be more complex to implement than equivalent combined-technology alternatives. Therefore, Alternatives 5R, 5R-Treatment, 6C, and 6R (with lower RALs) rank lower than the other alternatives.
- The CAD (2R-CAD) and treatment (5R-Treatment) alternatives have technical and administrative challenges associated with siting, permitting, operating, and maintaining either CAD facilities or a soil washing facility, and in addition for Alternative 5R-Treatment, finding an acceptable use for the clean fraction of treated sediment.
- Alternatives that rely more on MNR to achieve cleanup objectives have an increased potential for requiring actions in the future (e.g., more dredging or capping). This results in an increased technical and administrative burden of evaluating monitoring data over time, considering the need for contingency actions if cleanup objectives are not achieved in the predicted time frame, and implementing contingency actions. In this context, alternatives that rely to a greater extent on active construction to achieve cleanup objectives rank higher for administrative implementability.

Alternatives 4C, 4R, and 5C receive the highest rankings for implementability because they represent the best balance of the implementability factors. They are technically reliable and administratively feasible, and their large actively remediated surface areas are less likely to trigger additional actions.

Project sequencing is an important consideration from a recontamination perspective. The larger dredging alternatives (4R, 5R, and 6R) are more difficult to sequence in a specific order, because of the difficulties in coordinating multiple remediation projects and source control actions, administrative delays, and associated programmatic difficulties. Section 12.4.3 discusses an adaptive management approach for managing the sediment cleanup, and Section 10.2.3.4 evaluates the potential effects that sequencing may have on predicted site-wide sediment concentrations.

### 12.1.7 Cost

This criterion evaluates the capital, operation and maintenance, and monitoring costs of each alternative. Detailed cost estimates for each remedial alternative are presented in Appendix I, and summarized in Figure 10-7. The comparative analysis concluded that the alternatives differ significantly in costs (all costs are expressed as net present value at a discount rate of 2.3%):

- Alternative 6R has the highest costs ($810 million) and therefore ranks the lowest for this criterion (Table 12-1). Alternative 1 has the lowest cost at $9 million.[5] The estimated costs for the remaining alternatives range from Alternative 2R-CAD and 3C with the lowest cost and highest rank ($200 million) up to Alternative 6C ($530 million).
- Alternatives with a focus on combined technologies for a large portion of the active remediation (combined-technology alternatives) have lower costs than the corresponding alternatives that rely on dredging (removal) for active remediation (removal-emphasis alternatives) for the same RALs.

The cost estimates are sufficient for the purposes of this FS and fall within the +50%/-30% range of accuracy expected for an FS-level analysis. It should be noted that the uncertainties in these cost estimates are considerable, as shown in Table 12-1 and in the Appendix I cost tables.

### 12.1.8 State/Tribal and Community Acceptance

The last two modifying criteria, state/tribal and community acceptance, will be evaluated by EPA and the Washington State Department of Ecology (Ecology) after the FS is completed and this will include consideration of formal public comments on the Proposed Plan. However, EPA and Ecology have sought input of tribal and community groups during preparation of the FS, including quarterly meetings with resource agencies, community advisory groups, and tribal representatives, and have engaged with the community and tribes to review and comment on the remedial investigation (RI)/FS documents. In late 2010, EPA and Ecology invited the public to review and comment on the October 2010, Draft Final Feasibility Study for the Lower Duwamish

[5] The construction of the EAAs is not considered to be part of Alternative 1 (i.e., EAAs are assumed to have been completed prior to initiating the selected LDW remedy). Alternative 1 is $9 million, which includes LDW-wide monitoring, agency oversight, and reporting. The total cost of in-water design and cleanup actions in the EAAs is estimated to be $95 million. Costs for upland cleanup and source control activities associated with the EAAs are not included. The estimated costs for completing the EAAs are provided for informational purposes and are not included in the comparison of alternatives.

Waterway. More than 300 letters were received from individuals, businesses, interest groups, tribes, and government agencies. The comments were summarized in a March 2011 fact sheet. Input from the various outreach efforts conducted to date were used as an interim assessment of these modifying criteria in the comparative analysis of alternatives in Section 10.

## 12.2 Risk Management Principles and National Guidance

The LDW is one of many large and complex contaminated sediment sites in the country. Many sites in other regions are addressing similar issues and uncertainties. In response, EPA released the *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA 2002b) which can be found in Appendix A of the *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005b). This FS process has attempted to develop and evaluate the alternatives for the LDW in a manner consistent with these documents, most specifically with the 11 risk management principles set forth below:

1) **Control Sources Early:** Ecology is leading the source control program currently underway in the LDW. Implementation of this program is a long-term effort, and there are uncertainties as to how effective the program can be at preventing recontamination from diffuse sources in an urban watershed. Nevertheless, modeling efforts and empirical data collected to date suggest that the effects of lateral loadings should be localized once reasonable source control is attained to the extent practicable. However, model predictions estimate a range of long-term contaminant concentrations that are above some PRGs (natural background) and are influenced by ongoing urban inputs. Model predictions are corroborated by empirical trends observed in the LDW and other urban and nonurban water bodies.

2) **Involve the Community Early and Often:** Outreach and educational efforts for both tribal and community groups were conducted during preparation of the FS. The Duwamish River Cleanup Coalition (DRCC) is a local community advisory group that has been actively engaged in both RI and FS technical issues. DRCC is supported by a Technical Assistance Grant from EPA and a Public Participation Grant from Ecology. The baseline risk assessments evaluated potential site uses by local populations, including community members, tribal members, and Asian and Pacific islanders. These risk results have been factored into developing the long-term cleanup goals for the LDW. As the remedial alternative decision draws near, LDWG and the agencies will seek input from all affected parties, including the local landowners and businesses, the neighborhoods, and the broader ratepayer and taxpayer community who may fund some of these cleanups.

3) **Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees:** This FS is conducted under a joint order issued by EPA and

Ecology so state coordination is ensured. The Muckleshoot and Suquamish Tribes and the National Oceanic and Atmospheric Administration (NOAA) have all been closely involved in the studies completed to date on the LDW. EPA and Ecology have instituted a regular series of meetings with NOAA, the tribes, and the Washington State Departments of Natural Resources and Health. LDWG has participated actively in sharing key concepts and issues related to the cleanup. The input received from these parties has been very helpful in developing the FS.

4) **Develop and Refine a Conceptual Site Model that Considers Sediment Stability:** Empirical data and modeling have been used to develop a CSM of the LDW, which is summarized in Section 2 and described in detail in the RI (Windward 2010). The CSM indicates that the LDW is a net depositional system, with approximately 100,000 metric tons of sediment from upstream deposited within the LDW each year. Relatively small areas are subject to episodic scouring as a result of high-flow events or localized vessel activity within routine operating parameters. These areas have been considered in developing the alternatives, and are part of the areas designated for active management in Alternatives 2 through 6. As noted in Section 9.1.2.1 and 9.3.5, the effects of vessel maneuvering under emergency and high-power operations and marine construction are not included, and may be important factors for sediment stability and exposure of subsurface sediments. Additionally, the location of the LDW in an active earthquake area could affect sediment stability to an uncertain degree.

5) **Use an Iterative Approach in a Risk-based Framework:** Studies by the NRC (2007) and other independent, scientific peer reviews of sediment sites throughout the country (USACE 2008a, Cannon 2006) conclude that substantial uncertainties exist related to cleanup of complex sites such as the LDW and point to the necessity of using adaptive management strategies. Remedial alternatives that rely primarily on dredging to achieve risk-based goals may have practical limitations as a result of the effects of sediment resuspension and recontamination. The time frames for completing source control and sediment cleanup in the LDW may span decades. Performance of passive remedial technologies such as MNR may be slower than predicted. These limitations suggest that selection of the remedial alternative for the LDW should include an iterative approach.

6) **Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models:** A multimillion dollar study, completed over the past nine years, has been conducted and includes extensive site characterization and a sophisticated model for evaluating sediment stability and long-term recovery in the LDW. The studies and modeling completed to date indicate that the LDW is recovering naturally in

many areas and focused remedial actions can increase the rate of recovery. As with any set of studies, their predictive ability has many limitations that can be improved during the remedial design and implementation phases as new information is developed. These uncertainties have been considered in evaluating the alternatives and the effects of these uncertainties have been discussed in the comparative analysis of the alternatives.

7) **Select Site-specific, Project-specific, and Sediment-specific Risk Management Approaches that Will Achieve Risk-Based Goals:** As part of assembling the alternatives, ranges of remedial actions and RALs have been presented. These have been used to evaluate the reduction in risks that may be achievable under each alternative. None of the alternatives are predicted to achieve the sediment PRGs that are based on natural background. However, the results illustrate that a combination of cleanup methods, including selective removal actions at targeted locations and various containment technologies, when coupled with natural recovery, are predicted to be the most cost-effective approach for achieving the cleanup objectives (with institutional controls to manage residual risks). All alternatives are predicted to achieve the same risk levels but at different points in time and with varying levels of uncertainty. The alternatives have been compared to one another considering temporal and spatial aspects of the LDW and the overall risk reduction achieved under each alternative.

8) **Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals:** The RAOs developed for the LDW are based on the results of the baseline human health and ecological risk assessments (Windward 2007a and 2007b). The final cleanup levels will be determined by EPA and Ecology; this FS presents PRGs and cleanup objectives that form the starting point for establishing the cleanup levels. The sediment PRGs associated with each RAO are based on the results of the risk assessments or ARARs. The alternatives share the same PRGs and ultimately have the same risk management goals. The alternatives differ in the type and extent of active versus passive remediation, and hence have different levels of certainty and estimated time frames to reach these goals, with proportional long- and short-term effects.

9) **Maximize the Effectiveness of Institutional Controls and Recognize Their Limitations:** To be fully protective, the selected remedy will require institutional controls. Seafood consumption advisories are expected to continue indefinitely under all of the alternatives (potentially diminishing over time). Seafood tissue contaminant concentrations are predicted to increase in the short term as a result of dredging. Additional actions to improve the effectiveness of seafood consumption advisories were evaluated and discussed in this FS because many studies have shown

seafood consumption advisories to be of limited efficacy. Recommended actions for public education, outreach, and notification control elements are the same for Alternatives 2 through 6. Alternative 1 does not include institutional controls for managing residual risks, beyond those required under enforcement agreements governing the EAA work and the existing WDOH seafood consumption advisory. Alternatives that include significant containment components (such as capping) that leave contaminated sediment in place at depth will require additional institutional controls, such as restrictions on activities that could disturb the area with remaining subsurface contamination. Such controls have been successfully implemented at a wide range of sites regionally and nationally.

10) **Select Remedies that Minimize Short-term Risks while Achieving Long-term Protection:** FS alternatives include various combinations of active and passive remediation technologies. This allows each alternative's performance to be compared with respect to short-term risks and long-term protection. Although all the alternatives achieve similar long-term risk-reduction goals, the long-term effectiveness and permanence of the remedial alternatives are greatest for alternatives that remove larger volumes of contaminated sediments. Alternatives that provide for more engineered capping of contaminated sediments provide for greater long-term protection than those that rely on ENR and MNR. Conversely, short-term risks to the community and workers and environmental impacts are closely tied to the construction period for each alternative. Short-term risks during construction include worker safety, transportation-related impacts on communities, air emissions, habitat disruption, and increased contaminant concentrations in resident fish and shellfish tissue during dredging. In the MTCA DCA analysis, which can serve as a rough guide for evaluating total benefits versus risks, Alternatives 2 and 3 score lower, while Alternatives 4 through 6 score higher when these factors are considered collectively. The DCA analysis is used to screen disproportionately costly alternatives out of MTCA remedy selection analyses, not as a numerical ranking system for all alternatives.

11) **Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness:** Alternatives 2 through 6 include extensive short-term and long-term monitoring programs to assess effectiveness (see Appendix K) and the cost estimates assume contingency actions based on monitoring results. Alternative 1 includes long-term site-wide monitoring but does not assume any contingency actions based on the latter monitoring. Alternatives that include a substantial natural recovery component have monitoring programs that can be used to adapt the remedial alternative as new information becomes available. Monitoring data can be evaluated against performance metrics, and contingency actions

(e.g., dredging, capping, or ENR/*in situ*) may be implemented as identified in the Record of Decision (ROD). Remedial design will refine the monitoring and maintenance plans to address uncertainties in the conceptual site model (CSM).

## 12.3 Managing the Key Uncertainties

In an environment that is changing over time, decision-making on a site of the size and complexity of the LDW means accommodating areas of uncertainty. This FS has sought to rely on the best information and science available at this time, and where necessary, made reasonable assumptions to evaluate different remedial alternatives. The remaining sources of uncertainty in these analyses must be factored into the selection and implementation of a remedial alternative for the LDW. The nature and potential magnitude of key uncertainties are discussed in the detailed evaluation of alternatives (see Section 9.3.5).

While uncertainty assessments using bounding-level assumptions did not have significant effect on residual risks, two of the largest effects are associated with: 1) the quality of incoming sediment from the Green/Duwamish River and 2) the potential to expose subsurface contamination left in place following remediation. The following factors emerge as particularly important for managing uncertainty relative to the time predicted for achieving cleanup objectives and the anticipated performance of the alternatives:

- The sediment transport model and BCM predictions indicate that over the 45-year model period, the sediments depositing in the LDW will be dominated by upstream Green/Duwamish River solids. Ultimately, surface sediment contaminant concentrations are predicted to converge to levels similar to the quality of incoming sediment from the Green/Duwamish River and other inputs, resulting in similar levels of risk over time. While future conditions and actual contaminant concentrations are not certain (e.g., depending on the effectiveness of source control efforts), the BCM predicts that conditions will be similar in the long term, regardless of the alternative. The quantified uncertainty for modeled predictions is greater than the predicted differences in outcomes among alternatives or the differences predicted from bounding other uncertainties, as discussed below.

- Long-term SWAC predictions do not account for deep disturbances of subsurface contaminated sediments by mechanisms such as vessel scour and earthquakes. SWACs could be higher than model predictions, especially if disturbances are widespread and persistent. Alternatives 1 and 2, in particular, have the most uncertainty. The predicted SWACs for alternatives that leave less subsurface contamination (the higher numbered alternatives) are less sensitive to any increase associated with such disturbances.

However, persistence of any such increase in surface SWACs should be mitigated to some extent by making repairs as needed under the operation and maintenance (O&M) program.

- The performance of each remedial technology has some uncertainty associated with it. It is well documented that dredging produces dredge residuals that will elevate surface sediment and tissue contaminant concentrations over the short term. Capping and ENR/*in situ* may need periodic repairs and continued maintenance. MNR performance may be slower (or faster) or simply different than predicted and may require additional monitoring or contingency actions based on monitoring results. Many of these potential uncertainties have been incorporated into the cost estimates as contingency actions, repairs, or additional monitoring.
- Recent projects have shown that actual dredging volumes can be much higher than those estimated during the FS or remedial design phase. Volume estimates used in this FS incorporate additional contingency volumes based on experience at other sediment remediation sites. However, uncertainty remains and is managed in this FS by presenting a range of contaminated sediment volumes (see Appendix E) along with the cost and time impacts of dredging greater volumes.

Model assumptions are another source of uncertainty that need to be factored into the selection and implementation of a remedial alternative for the LDW. Key considerations include:

- Uncertainty in the predictions of resident seafood tissue concentrations and associated human health risks (from the total PCB SWAC estimates) are compounded by: 1) exposure assumptions from the human health risk assessment (Windward 2007b) such as seafood consumption rate, diet composition, and exposure frequency/duration and 2) assumptions used in food web model (FWM) predictions such as uptake factors and future water concentrations. The predicted future seafood tissue concentrations and associated risks for total PCBs could be overestimated or underestimated and should be viewed only as approximations. The predictions of resident seafood tissue concentrations and risks are nevertheless useful for comparing the alternatives to one another because the uncertainties in the FWM and risk assessment methods are the same for all alternatives, and therefore all of the alternatives should be affected similarly.
- A sensitivity analysis was conducted to evaluate uncertainties associated with net sedimentation rates, which may affect the rate at which natural recovery occurs, and the contaminant concentrations of incoming sediment. Despite the uncertainties in predicting the long-term sediment contaminant concentrations, the analysis concluded that the final long-term, model-

predicted contaminant concentrations are largely insensitive to the range of RALs evaluated in Alternatives 2 through 6. Results showed that variability in the contaminant input parameters was more important to recovery than the sedimentation rate, although localized sedimentation and scour effects could be important. Areas with both contamination and significant scour potential were prioritized for remedial action in the FS.

- As the RALs decrease (i.e., for higher-numbered, larger alternatives such as Alternatives 6C and 6R), the chances for additional actions being required as a result of recontamination above the RALs from continuing urban inputs increases. The highest probability of recontamination will be in localized areas, such as near outfalls (see Appendix J). Collectively, recontamination in localized areas is predicted to have only a small effect on the site-wide SWACs that can be achieved long term.
- The BCM developed for this FS allows for a semi-quantitative evaluation of source control effects on sediments. Location-specific analyses and coordination with the source control program will be required during the remedial design phase to ensure that source control is sufficient to proceed with remedial action. Long-term monitoring and source control measures will be necessary, regardless of the remedial alternative selected. This uncertainty can affect the predicted time to achieve cleanup objectives.

## 12.4 Next Steps

EPA, Ecology, and LDWG solicited input on the October 2010 Draft Final FS from the public, including a broad range of stakeholders, and incorporated the input received into this Final FS. EPA will issue a Proposed Plan that identifies a preferred remedial alternative for the LDW. Formal public comment will be sought on the Proposed Plan. After these comments are received and evaluated, EPA will select the final remedial alternative and issue the ROD. The cleanup standards, objectives, and RALs will be specified in the ROD, which is anticipated to be issued with state concurrence. The ROD may also specify interim (e.g., 5-year) goals and final post-construction goals for some or all passively remediated areas. After the ROD is issued, the first 5-year period is expected to include: completing any remaining early actions; conducting extensive source identification and control activities; negotiating one or more consent decrees for performance of remedial design and cleanup; conducting predesign investigations, baseline monitoring, and remedial designs; and developing both a compliance monitoring program for active cleanup areas and an O&M monitoring program. The long-term plan will be designed to assess achievement of cleanup objectives, evaluate performance of the cleanup, and trigger contingency actions and adaptive management steps as needed.

The CERCLA remedial actions will be one part of multiple efforts to improve the quality of the LDW and surrounding watershed. These efforts are multi-disciplinary, and will include coordinated efforts by EPA, Ecology, King County, the City of Seattle, the City of Tukwila, the Port of Seattle, WDOH, affected industries in the LDW watershed, and a number of other parties with particular interests in the LDW. As briefly discussed below, these efforts are three-fold: cleanup of the EAAs, ongoing source control efforts, and remediation and adaptive management of the sediments in the LDW beyond the EAAs.

### 12.4.1 Cleanup of the EAAs

There are five designated EAAs in the LDW. The parties responsible for the five EAAs have conducted an intensive study of each one, and cleanup has occurred at three of the five EAAs: the Duwamish/Diagonal EAA by King County in 2003 and 2004, the Norfolk EAA by King County in 1999 and The Boeing Company in 2003, and Slip 4 by the City of Seattle in 2012. Remedy decisions have been issued by EPA for the other EAAs: Terminal 117 and Boeing Plant 2/Jorgensen Forge.[6] Together, these five EAAs cover 29 acres, representing some of the highest levels of sediment contamination in the LDW. It is anticipated that cleanup of the EAAs will be completed prior to initiating any of the cleanup alternatives in the FS.

Additional agreed orders have been negotiated, or are being negotiated, with upland property owners along the LDW that have adjacent contaminated sediments. Ecology has 18 agreed orders in place with site owners or users (see Section 2.4). The scope of work included in these agreed orders often includes upland, shoreline, and sediment investigations, evaluation of sources to the LDW surface water and sediments, including near-field recontamination modeling, and an evaluation of remedial alternatives.

### 12.4.2 Ongoing Source Control Efforts

The LDW source control strategy (Ecology 2004) focuses on controlling contamination that affects LDW sediments. It is based on the principles of source control for sediment sites described in *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA 2002b) and similar Washington State requirements.

Ecology is the lead agency for coordinating and implementing source control efforts in the LDW and works in cooperation with local jurisdictions and EPA to create and implement the source control strategy and action plans and to prioritize upland cleanup efforts in the LDW. In 2002, the LDW Source Control Work Group (SCWG) was formed, which conducts several different source control activities within the LDW area. Primary members of the group include EPA, Seattle Public Utilities, King County, and the Port of Seattle. The LDW source control strategy also identifies various regulatory programs at EPA and Ecology that are called upon as needed for source control as well as several

[6] Note that Boeing Plant 2 and Jorgensen Forge are considered to be a single EAA, although the investigations and cleanups of those two sites are being conducted under separate regulatory authorities.

*ad hoc* members of the SCWG, including the City of Tukwila, Puget Sound Clean Air Agency, and the Washington State Departments of Transportation and Health. All LDW SCWG members are public entities with various source control roles, and the collective purpose is to share information, identify issues, develop action plans for source control tasks, coordinate implementation of various source control measures, and share progress reports on these activities.

Ecology developed the LDW source control strategy (Ecology 2004) to identify and manage sources of contaminants to LDW sediments and those activities are coordinated with the sediment cleanups addressed in the EAAs and in this FS. The strategy and associated Source Control Action Plans (SCAPs) for 24 individual drainage basins around the LDW provide the framework and process for identifying source control issues and implementing practical control of contaminant sources.

It is important to note that in some localized areas, some recontamination may occur even with aggressive source control because of the difficulty in identifying and completely controlling all potential sources of certain contaminants that are widely released by urban activities. The LDW source control strategy (Ecology 2004) describes how recontamination of LDW sediments will be controlled to the extent practicable. The goal is to limit sediment recontamination that exceeds location-specific standards, where feasible. The strategy also serves three other primary functions. First, it sets up the reporting process for tracking and documenting all of the source control work performed throughout the LDW source area. This information is necessary for EPA's administrative records and remedial decisions. Second, the strategy broadly prioritizes source control work according to the schedules proposed for sediment cleanups (e.g., EAAs, other areas to be identified in the ROD). Finally, the strategy identifies the following basic steps for performing source control: 1) identify, 2) characterize, and 3) control sources and pathways of contamination to the LDW.

EPA's (2002) sediment guidance recommends "control sources early, before sediment cleanup begins," but that may not always be practical. Delaying sediment cleanup until all sources have been identified and controlled, regardless of their contribution in terms of contaminant loading, may delay achieving many of the benefits that sediment cleanup alone can accomplish.

The LDW source control efforts have been developed in parallel with the RI and FS and will continue before, during, and after the implementation of the remedial alternatives discussed in this FS.

Source tracing and control efforts include:

- Mapping storm drain systems and conducting chemical analyses of samples collected therein
- Managing discharges from storm drains and combined sewer overflows (CSOs)

- Inspecting local businesses that discharge or otherwise contribute to storm drains, CSOs, or directly to the LDW, and implementing best management practices
- Conducting upland cleanups, including remediating contaminated soils, groundwater, and storm drain solids.

SCAPs document and prioritize source control activities for each source control area. Ecology's first priority was to address sources contributing to contamination in EAAs. Because of the dynamic nature of many source control activities, it is essential to maintain flexibility when adapting source control efforts to specific needs within source control areas. The success of source control depends on cooperation of all members of the SCWG and the active participation of businesses that must make changes to accomplish source control goals. This adaptive strategy for prioritizing source control work will continue throughout selection, design, and implementation of the long-term remedy for the LDW.

### 12.4.3 Adaptive Management for In-Water Sediment Remediation (Outside of the EAAs)

Remediation of contaminated sediments in the LDW under CERCLA should be undertaken in a flexible, iterative, and adaptive manner. Remediation should focus on cleaning up the most contaminated areas first to reduce risks the fastest, consistent with recommendations for remediation of contaminated sediment sites nationwide (NRC 2007, EPA 2005b). Next, learning from each incremental cleanup experience, further actions should be adjusted based on what has been learned. The cleanup process of the LDW should:

1) Remediate the most contaminated sediment areas first to reduce risks the fastest.
2) Continue source control efforts, sequenced to the sediment remediation.
3) Address uncertainties and provide flexibility in the design elements as more data become available. Use the results of early actions to inform further sediment cleanup.
4) Monitor performance and changing conditions in both the remediation and source control efforts.
5) Implement contingency actions that may become needed over time.

Experience at other complex sediment sites points to the necessity of using adaptive management strategies, as recommended by EPA guidance (EPA 2005b), the NRC (2007), and other independent, scientific peer reviews of sediment sites throughout the country (USACE 2008a, Cannon 2006). For adaptive management to work effectively, it must be informed by data. Further actions can be adjusted based on what has been learned from each incremental cleanup experience. A long-term monitoring plan will be established with metrics and analyses that meet clearly articulated data quality objectives. Baseline monitoring will be conducted prior to beginning the initial remedial activities to establish a benchmark for evaluating the effectiveness of the remediation. Collecting monitoring information during and after cleanup will help evaluate the effectiveness of the selected remedial alternative, and trigger the planning and execution of contingency actions as needed. Because remediation and source control efforts may take years if not decades to occur, and biological response may take even longer, monitoring the changes in contaminant inputs and responses of various media in the LDW will be important to help determine when and to what extent contingency actions may be needed. Contingency actions may include more sediment remediation, source control efforts, or in particular, changes to interim or final objectives of the remedy that reflect the best that can be practicably accomplished.

EPA will evaluate the effectiveness of the selected remedial alternative no less frequently than once every five years. The 5-year reviews can integrate comprehensive evaluations of the seafood consumption advisories, outreach and education programs, source control work, and changes in overall waterway health. These periodic reviews can be used by EPA in conjunction with the performance monitoring program to identify the need for any additional course corrections (e.g., contingency actions, review endpoints, modify technologies, conduct more monitoring, etc.) in the cleanup.

## Table 12-1 Summary of Alternatives: Costs, Technologies, and Overall Protection of Human Health and the Environment

| | Analysis Parameters | Remedial Alternative 1 | 2R | 2R-CAD | 3C | 3R | 4C | 4R | 5C | 5R | 5R-T | 6C | 6R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs and Technology Application Summary | ***Costs ($Millions)*** | | | | | | | | | | | | |
| | Capital, O&M, and Monitoring Costs (best estimate based on net present value) | 9 [a] | 220 | 200 | 200 | 270 | 260 | 360 | 290 | 470 | 510 | 530 | 810 |
| | Cost Accuracy Range of -30% to +50% [b] | n/a | 150 – 320 | 140 – 290 | 140 – 300 | 190 – 400 | 180 – 390 | 250 – 540 | 200 – 440 | 330 – 700 | 360 – 760 | 370 – 790 | 570 – 1,200 |
| | ***Remedial Footprint (Area in acres)*** | | | | | | | | | | | | |
| | Dredge | n/a | 29 | 29 | 29 | 50 | 50 | 93 | 57 | 143 | 143 | 108 | 274 |
| | Partial Dredge and Cap; Cap | n/a | 3 | 3 [c] | 19 | 8 | 41 | 14 | 47 | 14 | 14 | 93 | 28 |
| | ENR/*in situ* | n/a | 0 | 0 | 10 | 0 | 16 | 0 | 53 | 0 | 0 | 101 | 0 |
| | MNR | n/a | 125 | 125 | 99 | 99 | 50 | 50 | 0 | 0 | 0 | 0 | 0 |
| | Verification Monitoring | n/a | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 0 | 0 |
| | Total Active Area [d] | n/a | 32 | 32 | 58 | 58 | 107 | 107 | 157 | 157 | 157 | 302 | 302 |
| | ***Volume and Construction Time Frame*** | | | | | | | | | | | | |
| | Total Dredge Volume (cubic yards) | n/a | 580,000 | 580,000 | 490,000 | 760,000 | 690,000 | 1,200,000 | 750,000 | 1,600,000 | 1,600,000 | 1,600,000 | 3,900,000 |
| | Construction Period (years) | 0 | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| Overall Protection of Human Health and the Environment | ***Time to Achieve Cleanup Objectives (years)*** | | | | | | | | | | | | |
| | RAO 1: $10^{-4}$ magnitude PCB risk (Adult Tribal RME) [e] | 5 | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| | RAO 1: Predicted time for total PCBs and dioxins/furans to reach long-term model-predicted concentration range in surface sediment (in years) [e] | 25 | 24 | 24 | 18 | 21 | 21 | 21 | 17 | 22 | 22 | 16 | 42 |
| | RAO 2: Total direct contact excess cancer risk $\leq 1 \times 10^{-5}$ and all non-cancer HQs < 1 (All exposure scenarios) [f] | 5 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 |
| | RAO 2: Individual risk from cPAHs $\leq 1 \times 10^{-6}$ in all areas except Beach 3 | 25 | 19 | 19 | 3 | 6 | 3 | 6 | 3 | 6 | 6 | 3 | 6 |
| | RAO 3: Ecological protection of benthic invertebrates (SQS) [g] | 20 | 14 | 14 | 8 | 11 | 6 | 11 | 6 | 11 | 11 | 6 | 11 |
| | RAO 4: Ecological protection for wildlife – river otter (HQ <1) [h] | <5 | 4 | 4 | 3 | 6 | 6 | 11 | 7 | 17 | 17 | 16 | 42 |
| | ***Effects Due to Construction*** | | | | | | | | | | | | |
| | Air Quality Impacts ($CO_2$/$PM_{10}$; metric tons) | n/c - n/c | 20,000/17 | 17,000/18 | 19,000/15 | 27,000/23 | 27,000/22 | 42,000/35 | 30,000/25 | 60,000/50 | 51,000/44 | 64,000/53 | 139,000/118 |
| | Truck and Train Transportation (miles) [i] | n/c | 480,000 | 227,000 | 404,000 | 620,000 | 560,000 | 940,000 | 610,000 | 1,380,000 | 1,010,000 | 1,380,000 | 3,170,000 |
| | Risk Reduction: Predicted % of PCB SWAC Reduction from Baseline Attributable to Construction Only (Active Remediation) | 49% | 59% | 59% | 62% | 62% | 67% | 67% | 72% | 72% | 72% | 87% | 87% |
| | ***Magnitude of Residual Risk*** | | | | | | | | | | | | |
| | Post-construction number of core stations remaining >CSL in the FS dataset (under caps / all other locations) [j] | 70 outside of EAAs [k] | 0/37 | 0/37 | 15/32 | 1/24 | 18/26 | 1/14 | 20/22 | 1/5 | 1/5 | 27/8 | 1/0 |

Notes:

a. Alternative 1 costs ($9 million) are for LDW-wide monitoring, agency oversight, and reporting and do not include O&M. The cost of cleanup actions in the EAAs is estimated at approximately $95 million. The EAA cleanup action costs are provided for informational purposes and are not used in the comparison of alternatives.
b. The estimated ranges of costs are related only to the sediment cleanup actions; potential upland source control costs could be significant but are not included; EAA costs are also not included in Alternatives 2 through 6.
c. Alternative 2R-CAD includes the construction and use of CAD facilities within the LDW and encompasses an additional 23 acres of capped contaminated sediment.
d. Total active area excludes the 29 acres managed by the EAAs. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively.
e. No remedial alternative achieves RAO 1 PRGs without an ARAR waiver. All alternatives achieve protectiveness with some combination of active and passive remediation and ICs. Two time frames are provided for purposes of comparing the alternatives: 1) the point at which the alternatives reduce the Adult Tribal RME seafood consumption risk to $10^{-4}$, and 2) the predicted time for risk-driver concentrations to achieve long-term model-predicted concentration ranges. The former is provided for information only. The latter are based on achieving a site-wide total PCB SWAC within 25% (≤ 49 µg/kg dw) of the 45-yr Alternative 6R total PCB SWAC of 39 µg/kg dw, and a site-wide dioxin/furan SWAC within 25% (≤ 5.4 ng TEQ/kg dw) of the 45-yr Alternative 6R dioxin/furan SWAC of 4.3 ng TEQ/kg dw. Resident fish and shellfish tissue concentrations are expected to remain elevated during construction and up to 2 years after construction as a result of resuspension and release of total PCBs into the water column.
f. See Figure 10-4 for times for individual risk drivers to achieve excess cancer risk thresholds. Alternatives 3C and 3R specifically address direct contact risks and achieve the total and individual direct contact risk metrics defined in Section 9.1.2.3 at the end of construction for all exposure scenarios. The FS assumes that the Alternative 3 actions occur at the beginning of Alternatives 4, 5, and 6; these alternatives are assumed to have the same times to achieve the other cleanup objective metrics for RAO 2 as described for Alternatives 3C and 3R. Alternative 2 does not actively remediate for all direct contact risks. However, surface sediments in clamming and beach play areas are $\leq 1 \times 10^{-5}$ following construction of the EAAs and are expected to continue recovering naturally over time.
g. The time to achieve cleanup objectives for RAO 3 was assumed for purposes of the FS to be when at least 98% of FS surface sediment dataset stations are predicted to comply with the SMS and more than 98% of the LDW surface area is predicted to comply with the SMS. This is not intended as a compliance metric. EPA and Ecology will determine the appropriate metric for SMS compliance.
h. The time to achieve the cleanup objective for RAO 4 is when wildlife seafood consumption HQ <1 is achieved based on the site-wide total PCB SWAC at the end of construction.
i. Short-term impacts to workers, the community, and the environment are assumed to be proportional to the volume of material managed and the length of construction. Transportation (truck and train miles) is a surrogate for total volume managed. It is one particular metric that affects the community. See Table 10-3 for other short-term metrics.
j. Remaining cores grouped by those located under caps and those located anywhere else within the LDW after construction.
k. Alternative 1 has 25 core stations remaining in Category 1.

AOPC = area of potential concern; ARAR = applicable or relevant and appropriate requirement; BCM = bed composition model; C = combined technology; CAD = contained aquatic disposal; cPAH = carcinogenic polycyclic aromatic hydrocarbon; $CO_2$ = carbon dioxide; CSL = cleanup screening level; dw = dry weight; EAA = early action area; ENR = enhanced natural recovery; EPA = U.S. Environmental Protection Agency; FS = feasibility study; HQ = hazard quotient; ICs = institutional controls; kg = kilograms; LDW = Lower Duwamish Waterway; µg = micrograms; MNR = monitored natural recovery; n/a = not applicable; n/c = not calculated; ng = nanograms; O&M = operation and maintenance; PCB = polychlorinated biphenyl; $PM_{10}$ = particulate matter with a diameter of 10 micrometers or less; PRG = preliminary remediation goal; RAO = remedial action objective; RME = reasonable maximum exposure; R = removal emphasis; SMS = Sediment Management Standards; SQS = sediment quality standard; SWAC = spatially-weighted average concentration; T = treatment; TEQ = toxic equivalent

## Figure 12-1 Comparative Analysis of Remedial Alternatives

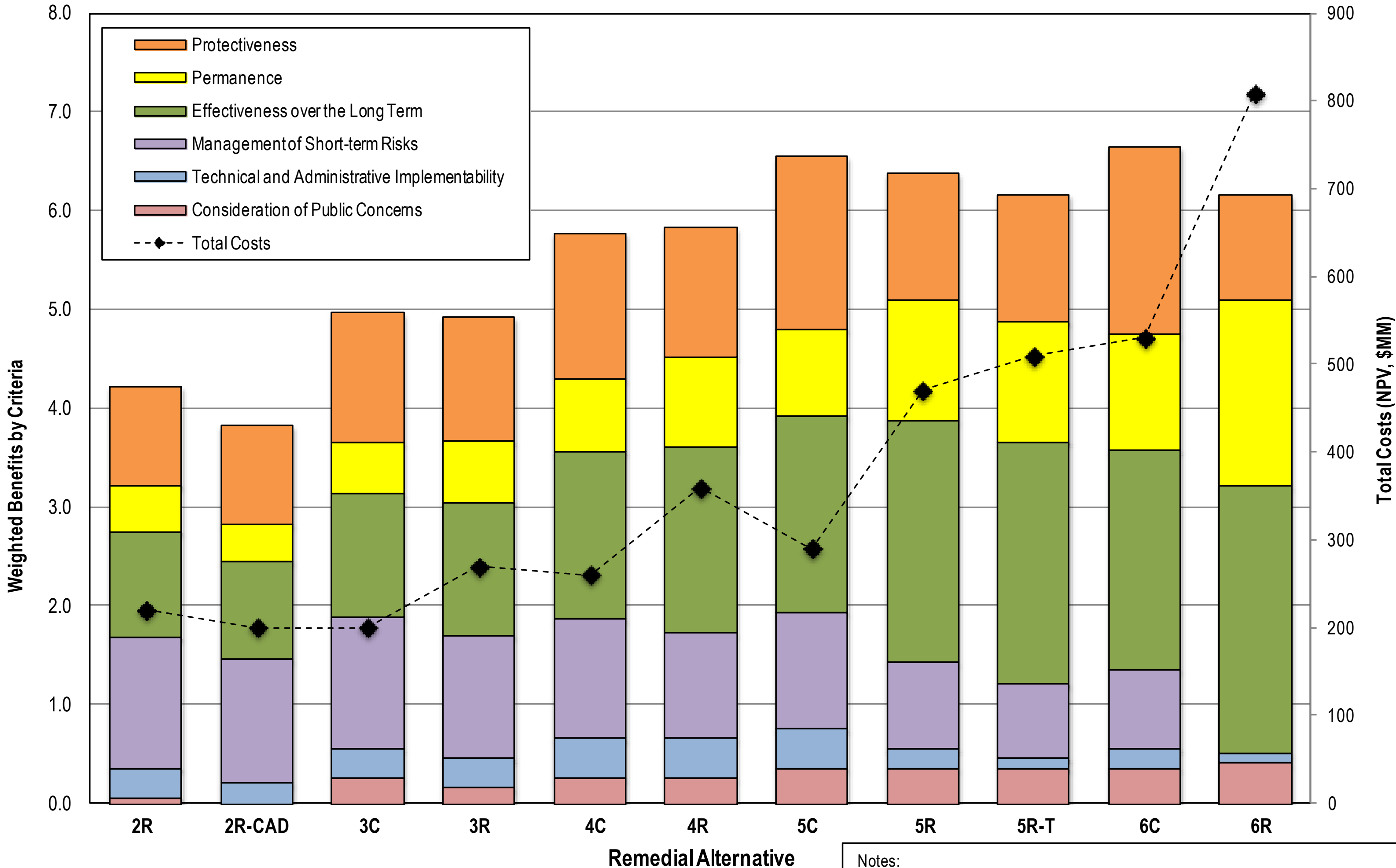
| Remedial Alternative | Cost (Net Present Value) | CERCLA Evaluation of Alternatives [a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Achieve Threshold Requirements[b] | Reduction in Toxicity, Mobility or Volume through Treatment [c] | Long-term Effectiveness and Permanence | Short-term Effectiveness | Implementability | Cost [d] |
| 1 | $9 MM [e] | No | Low | Low | Low | Relatively high | Very high |
| 2R | $220 MM | Yes | Low | Low-moderate | Low-moderate | Moderate | Relatively high |
| 2R-CAD | $200 MM | Yes | Low | Low | Low-moderate | Low-moderate | Relatively high |
| 3C | $200 MM | Yes | Low-moderate | Moderate | Relatively high | Moderate | Relatively high |
| 3R | $270 MM | Yes | Low | Moderate | Moderate | Moderate | Moderate |
| 4C | $260 MM | Yes | Low-moderate | Relatively high | Relatively high | Relatively high | Moderate |
| 4R | $360 MM | Yes | Low | Relatively high | Moderate | Relatively high | Low-moderate |
| 5C | $290 MM | Yes | Moderate | Relatively high | Relatively high | Relatively high | Moderate |
| 5R | $470 MM | Yes | Low | Very high | Low-moderate | Low-moderate | Low-moderate |
| 5R-Treatment | $510 MM | Yes | Relatively high | Very high | Low-moderate | Low | Low-moderate |
| 6C | $530 MM | Yes | Moderate | Relatively high | Low-moderate | Low-moderate | Low-moderate |
| 6R | $810 MM | Yes | Low | Very high | Low | Low | Low |

Notes:
1. State, tribal, and community acceptance will be evaluated following formal public comment on EPA's Proposed Plan.
a. Ratings based on rankings shown in Table 10-1.
b. Threshold requirements are: 1) Overall Protection of Human Health and the Environment and 2) Comply with or waive ARARs.
c. *Ex situ* treatment (soil washing) is a component of only Alternative 5R-Treatment. *In situ* treatment is a component of the combined-technology alternatives.
d. Low costs are given a high rank and high costs are given a low rank.
e. Alternative 1 costs ($9 million) are for LDW-wide monitoring, agency oversight, and reporting. The cost of cleanup actions in the EAAs is estimated at approximately $95 million. The EAA cleanup action costs are provided for informational purposes and are not used in the comparison of alternatives.

Legend:
- Very high - Ranks very high compared to other alternatives
- Relatively high - Ranks relatively high compared to other alternatives
- Moderate - Ranks moderate compared to other alternatives
- Low-moderate - Ranks low-moderate compared to other alternatives
- Low - Ranks low compared to other alternatives

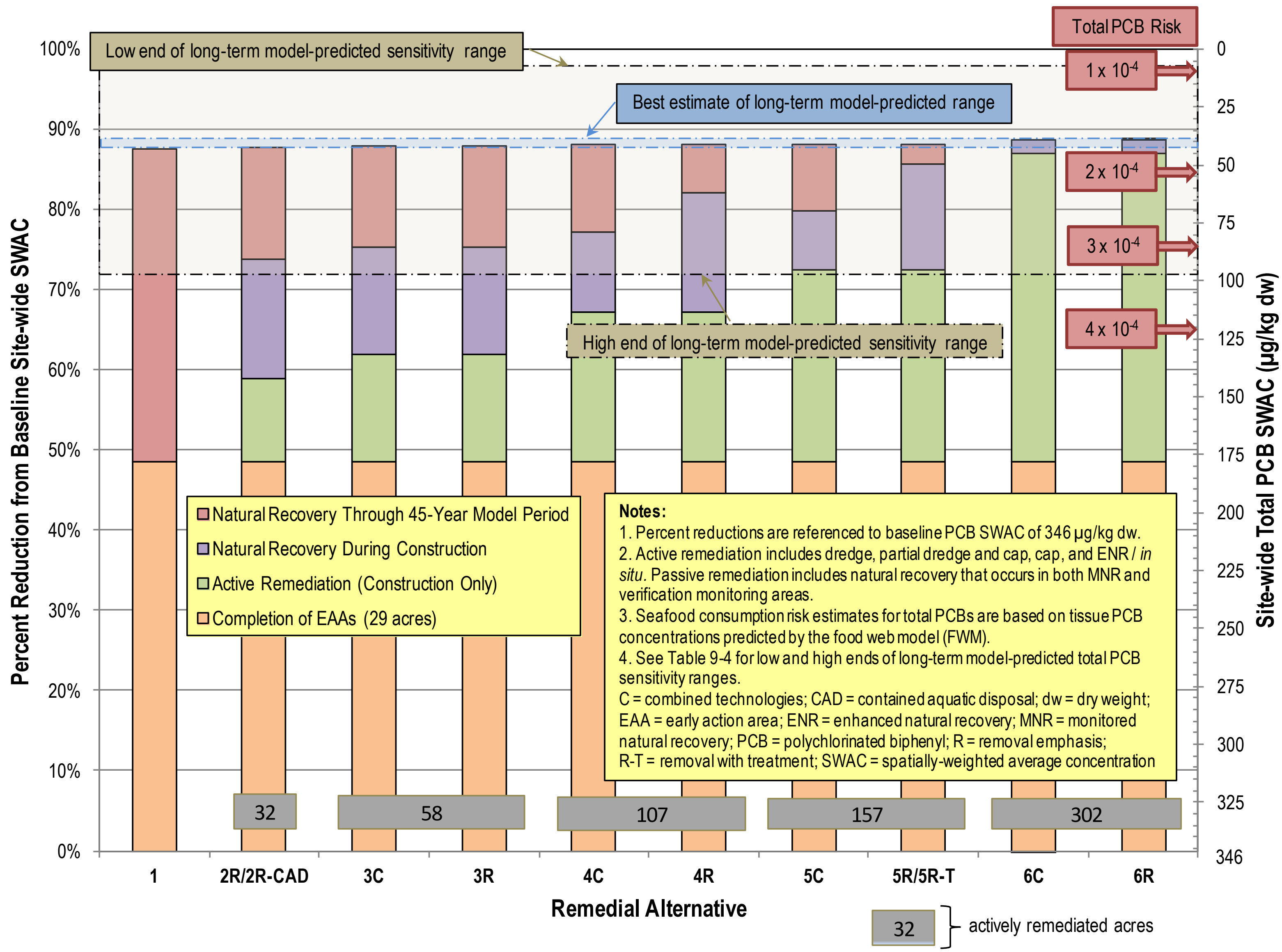
ARAR = applicable or relevant and appropriate requirement; C = combined technologies; CAD = contained aquatic disposal; CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; EAA = early action area; EPA = U.S. Environmental Protection Agency; FS = feasibility study; LDW = Lower Duwamish Waterway; MM = million; R = removal emphasis

**Figure 12-2 MTCA DCA Weighted Benefits by Criteria and Associated Costs for the Remedial Alternatives**




Notes:
1. See Table 11-6 for details on weighted benefits for individual evaluation criteria.
2. Total weighted benefit represents rounded values and weighted benefits by criteria represent unrounded values.
C = combined-technology alternative; CAD = contained aquatic disposal;
DCA = disproportionate cost analysis; MM = million; MTCA = Model Toxics Control Act;
NPV = net present value; R = removal-emphasis alternative; R-T = removal with treatment

**Figure 12-3 Reduction of Total PCB SWAC by Active Remediation and Natural Recovery**



# Lower Duwamish Waterway Group

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

## Section 13
## References

# 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

**October 31, 2012 (revised November 5, 2012)**

**Prepared by:** AECOM

710 Second Avenue, Suite 1000 • Seattle, Washington • 98104

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