Technical Memorandum

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To: Allison Hiltner, EPA; Brad Helland, Ecology

From: Lower Duwamish Waterway Group

Subject: Key Elements for Optimizing the Cleanup of the LDW

1.0 Introduction

The Draft Final Feasibility Study (FS) for the Lower Duwamish Waterway (LDW) was submitted to the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) in October 2010. Significant public, stakeholder, and technical expert input was received by EPA and Ecology and incorporated into comments provided to LDWG in February of 2011. The Lower Duwamish Waterway Group (LDWG) is currently updating and finalizing the Draft Final FS to reflect this input, under direction from EPA and Ecology.

The purpose of this memorandum is to identify key elements of a site remedy that draw from the most effective features of the remedial alternatives for the LDW that were presented in the Draft Final FS and include new ideas based on EPA, Ecology, and stakeholder feedback. In addition, in response to stakeholder comments, LDWG has identified predesign elements that could be conducted concurrently to help support a timely implementation of the final remedy, regardless of the alternative ultimately selected. This memorandum synthesizes these elements and focuses on the following benefits:

- Reducing human health risks as early as possible.
- Reducing the time to achieve the remedial action objectives (RAOs) faster than any alternative in the FS.[1]
- Minimizing short-term impacts to the community and environment.
- Ensuring the long-term effectiveness and permanence of the remedy.

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1 Achievement of RAO 1 will require a combination of active remedial measures, natural recovery, and institutional controls because no alternative can achieve the Model Toxics Control Act's human health protection standard solely by reducing sediment contaminant concentrations through active remediation. However, risks can be reduced to protective levels through a combination of active remediation, source control, natural recovery, and institutional controls, with institutional controls being used only to the extent further remedial measures cannot practicably achieve further risk reductions.

- Increasing certainty through reduced reliance on natural recovery for achieving human health goals, aggressively reducing bioavailability, proactive predesign efforts, and robust monitoring and response plans.
- Using active remediation to achieve human health risk reductions and focusing monitored natural recovery (MNR) primarily on achieving protection of the benthic community. Natural recovery processes will continue in the LDW after these risk goals are achieved and will continue to be monitored for effectiveness. Corrective action plans will be in place to address any unexpected re-exposures or problems.
- Retaining design flexibility to help ensure the best solution is applied at each location.

The key elements of a site remedy that would achieve the benefits listed above include:

- A combination of remedial action levels (RALs), drawn from those presented in the Draft Final FS, that prioritize human health risk reduction.
- Optimized technology assignments with a focus on dredging and capping the most contaminated areas and in less contaminated areas as needed to maintain beneficial uses (e.g., habitat, navigation depths); enhanced natural recovery (ENR), *in situ* treatment, and scour mitigation technologies in moderately contaminated areas; and MNR in relatively less contaminated areas.
- Focused predesign studies to add certainty to predicted outcomes and to accelerate cleanup implementation.
- A commitment to proactive adaptive management approaches that include design flexibility, comprehensive monitoring, planning for contingency actions, and institutional controls.

EPA and Ecology could combine these key elements into a comprehensive cleanup that protects human health and the environment, is consistent with national guidance on management of contaminated sediment, and responds to the broad range of public input on the Draft Final FS. The expected results include:

- One of the shortest construction time frames (5 years) as compared to the time frames of the individual alternatives evaluated in the Draft Final FS, accomplished by combining elements from the various alternatives.
- The quickest aggregate reduction of risks from polychlorinated biphenyls (PCBs) to people who consume resident seafood (RAO 1).
- The same reduction in direct contact risks (RAO 2) as Alternatives 3 through 6, achieved as quickly as any alternative.
- RAO 3 (protection of the benthic community) and RAO 4 (protection of wildlife) achieved immediately after construction.[2]

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[2] The time frame for RAO 3 assumes natural recovery continues to occur during construction. For RAO 4, an additional 1 to 2 years of recovery in fish/shellfish tissue contaminant concentrations may be required after construction to reduce the short-term effects associated with dredging operations and achieve the RAO.

- A solution that benefits all users by prioritizing human health risk reduction, optimizing the technology assignments and reducing the construction time.

The key elements are discussed individually and then combined to offer a demonstration of how combining them might compare in benefits and costs to the remedial alternatives evaluated in the Draft Final FS. The comparisons of the combined elements approach to the alternatives presented in Sections 3.2 and 3.3 of this memorandum are based on current working draft revisions to the remedial alternatives for the Final FS to make the comparisons more relevant.

2.0 Key Elements

The four key elements include: 1) a combination of RALs, 2) optimized technology assignments that include increased reliance on *in situ* treatment and scour mitigation options for potential scour areas, 3) predesign studies, and 4) proactive adaptive management commitments to ensure that cleanup objectives are achieved.

2.1 Remedial Action Levels – Prioritizing Human Health

The RALs are the point-based concentrations of risk-driver contaminants in surface sediments above which active cleanup measures (dredging, capping, ENR) are required. The Draft Final FS contained five sets of RALs for total PCBs, arsenic, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), dioxins/furans, and Sediment Management Standards (SMS) chemicals. This array was selected to evaluate how incremental reductions of the RALs affected the time and cost to achieve the RAOs. Based on these analyses and the feedback LDWG received from EPA, Ecology, and stakeholders, an optimized set of RALs are presented in Table 1.

Table 1 Remedial Action Levels and Technology Application Limits

Risk-Driver	Concentration Units	Remedial Action Levels[a]	Upper Concentration Limits for ENR or ENR/*in situ* Treatment[b]
Total PCBs	µg/kg dw	240[c]	1,300
Arsenic	mg/kg dw	57/28[d]	93
cPAHs	µg TEQ/kg dw	1,000/900[d]	3,000
Dioxins/Furans	ng TEQ/kg dw	25	50
Other SMS chemicals	Chemical-specific	SQS10[e]	CSL[f]

Notes:

a. RALs also apply to subsurface sediment concentrations in potential scour areas in accordance with current Draft Final FS technology assignments

b. If surface sediment contaminants are above the upper concentration limits, then dredging or capping will be applied.

c. Implementation of this RAL would be based on the oc-normalized SQS value of 12 mg/kg oc, because oc-normalization considers the bioavailability of contaminants in the sediment.

d. Site-wide RAL/Intertidal RAL.

e. SQS10 is evaluated by the process identified in the Draft Final FS.

f. Limits to be determined during design on a chemical-specific basis.

cPAH = carcinogenic polycyclic aromatic hydrocarbon; CSL = cleanup screening level; ENR = enhanced natural recovery; oc = organic carbon; PCB = polychlorinated biphenyl; RAL = remedial action level; SMS = Sediment Management Standards; SQS = sediment quality standards; SQS10 = initial concentration expected to achieve the SQS through natural recovery within 10 years after construction is complete; TEQ = toxic equivalent

The RALs in Table 1 were identified to focus on achieving the fastest reductions in human health risks. As such, RALs from Alternative 5 are used for human health risk drivers. RALs from Alternative 4 are used for the remaining SMS chemicals. These RALs were combined with new upper concentration limits for ENR/*in situ* treatment that require dredging or capping in areas with higher concentrations of human health risk drivers and allow faster actions to be used in areas with moderate concentrations of human health risk drivers, where ENR with *in situ* treatment is applicable. The net result is quicker human health and ecological risk reduction and greater use of *in situ* treatment as compared to the Draft Final FS alternatives.

2.2 Technology Assignments – Optimized to Maintain Design Flexibility and Ensure Performance

The technologies assigned to individual areas of the LDW are based on site conditions such as contaminant concentrations, recovery potential, and scour potential. The Draft Final FS included technology assignment assumptions for the combined alternatives. To optimize design flexibility and ensure remedy performance, these assumptions are modified as follows:

- Increased use of *in situ* treatment to reduce the bioavailability of contaminants.
- Establishing upper concentration limits for application of ENR or ENR/*in situ* treatment. Areas where surface sediment contaminant concentrations are above the upper concentration limits would be dredged or capped to improve the long-term reliability of the remedy.
- Using ENR or ENR/*in situ* treatment in conjunction with scour mitigation technologies in potential scour areas.

The technology assignments include: *in situ* treatment, dredging, capping, ENR, MNR, and other remedial elements as described below.

2.2.1 Application of ENR/*In situ* Treatment Technologies

ENR is applied in areas of moderate contamination with net sedimentation and limited scour potential. ENR (and ENR with *in situ* treatment) can be combined with scour mitigation technologies to expand their applicability to some potential scour areas (see below for scour mitigation options).

A key element that can be used to optimize the cleanup is inclusion of, and increased reliance on, more *in situ* treatment to address human health risk drivers than is currently presented in the Draft Final FS. ENR can readily be combined with *in situ* treatment under various engineering approaches that can be tailored to site-specific conditions. Similar to the Draft Final FS, this approach assumes placement of 9 inches of sand for ENR, which is enhanced with activated carbon or organoclays to provide *in situ* treatment in all ENR areas. The analysis and costs presented in this memorandum assume up to 100 percent of the ENR areas will include *in situ* treatment. *In situ* treatment reduces the bioavailability of hydrophobic organic contaminants by adding various sorptive materials into the biologically active surface sediment layer. The two most common materials used for *in situ* treatment are activated carbon and organoclays. Organic contaminants such as PCBs, dioxins/furans, and cPAHs in the sediment readily bind to the activated carbon. This reduces the bioavailability to benthic organisms and also reduces the contaminant flux into the water column or sediment porewater, thereby reducing contaminant accumulation in the aquatic food web. Organoclays, on the other hand, are naturally occurring clays that are processed to replace the metal ions with amines or other functional groups; specific functional groups allow the processed clays to bind specific contaminants, such as cPAHs, metals, dioxins/furans, and PCBs.

2.2.2 Capping and Dredging Above the Upper Concentration Limits for ENR or ENR/*In situ* Treatment

Areas with contaminant concentrations above the RALs but not suitable for ENR or *in situ* treatment, or that have surface sediment contaminant concentrations greater than the upper concentration limit for ENR/*in situ* treatment, would be dredged or capped. Best management practices and conservation measures would be used during construction to reduce residuals generation, to incorporate habitat enhancements, and to generally reduce, limit, or mitigate short-term adverse effects.

2.2.3 MNR

Use of MNR would be limited to certain SMS chemicals that are not human health risk drivers and to areas where chemicals are above the sediment quality standards (SQS), but which are expected to recover through natural recovery within 10 years. In addition, verification monitoring (VM) is included as part of the predesign studies (see Section 2.3), to further refine the areas that would be appropriate for MNR.

2.2.4 Design Flexibility and Other Remedial Elements

Scour Mitigation

The existing technology application criteria in the Draft Final FS do not include ENR or *in situ* treatment in areas prone to scour (from high-flow events or propeller wash). While suitable for assumptions in an FS, more flexibility in these criteria can be included to allow appropriate remedial solutions to be engineered for site-specific needs. Scour is an important remedial design consideration when contaminated sediments that could be re-exposed are left in place. To date, most actual field applications of both ENR and *in situ* treatment have been in relatively quiescent sediment environments. However, a number of tested engineering technologies are available for mitigating scour impacts in intertidal environments and around structures (e.g., bulkheads, piers). These technologies include: 1) engineered aggregate mixes such as gravel and natural sediment containing naturally occurring organic compounds, with particles sized for self-armoring, as needed to stabilize sediments, or 2) engineered products such as mats or geogrids.

Merging scour mitigation technologies with ENR and *in situ* treatment can extend the applicability of these technologies into more energetic environments while preserving other important values (e.g., habitat, navigation depths). An optimized strategy includes moving forward with field or laboratory studies to further advance demonstration of these scour mitigation technologies combined with ENR or ENR/*in situ* treatment (see Section 2.3).

The Final FS will include technology descriptions of both *in situ* treatment technologies and scour mitigation technologies to allow these to be considered in the remedy decision. This memorandum assumes that a combination of engineering options would be used as necessary to enable placement of ENR/*in situ* treatment in potential scour areas.

Monitoring and Contingency Actions

Similar to alternatives in the Draft Final FS, the conceptual structure of a multi-component monitoring program would include baseline data (for comparison to future trends), location-specific data for remedial design, construction and post-construction monitoring (to ensure compliance with design objectives), technology performance monitoring, and long-term monitoring (to evaluate progress toward and achievement of the cleanup goals), as outlined in Appendix K of the Draft Final FS.

An optimized monitoring approach would set clear contingency actions for areas assigned to MNR, ENR, and *in situ* treatment if they do not achieve or are not predicted to achieve their performance goals. Monitoring results and the 5-year review process would regularly check on the reliability of technologies applied and would be used to assess the need for contingency actions. An optimized monitoring and contingency action program should also include the common elements of all remedial alternatives, including continued source control and institutional controls.

2.3 Investing in Predesign Studies

In discussion between EPA, Ecology, and LDWG on the stakeholder comments received on the Draft Final FS, the parties have realized that predesign studies could add certainty about predicted outcomes and accelerate implementation of the overall cleanup. These early studies would help inform technology assignments and subsequent remedial design work. By initiating these studies before the record of decision (ROD), remedial design and construction could be more quickly implemented. Other activities such as baseline data collection, remedial design sampling activities, and a study to evaluate the relationship between clam tissue and sediment concentrations of arsenic and cPAHs could be conducted after the ROD is finalized.

Surface Sediment Data and Evaluation of Recovery Trends

Approximately 23 acres of surface sediment in the LDW were above the SQS at baseline but are expected to be below the SQS by the time remedial design begins. These areas have been designated for VM in the Draft Final FS for Alternatives 2 through 5 because they are in areas with net sedimentation; they have no scour potential; they had only minor chemical exceedances above the SQS; and the data used to characterize the surface sediment contamination are over 10 years old. These 23 acres are also identified for VM in this memorandum.

To confirm that natural recovery processes are occurring, locations within these areas would be resampled to verify that concentrations have decreased over time and to validate or refine model predictions. The study design could focus on areas with particular attributes (e.g., intertidal areas, areas near outfalls where source control activities are underway or have been completed, areas with uncertain sedimentation rates) to answer specific questions regarding MNR applicability. This would improve the certainty of ENR and MNR performance when selected for specific areas of the LDW.

Results from this sampling and analysis effort could refine and add certainty to the natural recovery model predictions and potentially inform the prioritization of source control actions. Results may also be used to help guide final technology assignments made during remedial design.

Engineering Studies

Several laboratory and field demonstration projects using carbon amendments around the country have had promising results, providing proof-of-concept that the bioavailability of contaminant concentrations in surface sediment is significantly reduced. ENR applications have had similar success, but both applications rely on stability of the sediment bed to prevent scour and substantial loss of material. A site-specific study for the LDW would be valuable to assess both performance and delivery methods. Field demonstrations of ENR and *in situ* carbon amendment technologies would aid in evaluating site-specific application in the LDW. In particular, demonstrations/analyses could evaluate ENR/*in situ* treatment in combination with scour mitigation technologies in scour areas and intertidal areas. Results from this evaluation could be used to guide the final technology assignments for the selected remedy and establish performance metrics for ENR with *in situ* treatment.

Fish/Shellfish Tissue and Seafood Consumption Practices

An in-depth understanding of the social and life practices of communities living and recreating around the LDW could help develop the Institutional Controls Implementation Plan for long-term management of the LDW. This effort could include working with the community to conduct a public outreach survey of local populations, with a two-fold objective: 1) provide a deeper understanding of how the community uses the LDW, and 2) develop a risk communication strategy to help LDW users and neighbors understand their risks and how to minimize them over the duration of active remediation and beyond. The survey would build on information gathered during the remedial investigation and risk assessments, as well as the 2010 survey conducted by the Environmental Coalition of South Seattle (ECOSS 2011). As a follow-up to the survey, additional data on species-specific fish/shellfish tissue concentrations could be collected to provide updated information for outreach to local communities regarding seafood consumption risks.

2.4 Managing Uncertainty Adaptively

Adaptive management must be a key element of any LDW remedy. This includes a comprehensive monitoring program with periodic checkpoints, a commitment to revisit decisions based on new information, and defined contingency measures with assurance of adequate funding. Other key aspects include ongoing source control, and a broad institutional controls program consisting of seafood consumption advisories, public outreach and education, restrictive covenants, and assessing remaining risks to the community following active cleanup.

The need for adaptive management is related to the fact that the cleanup of the LDW is unusually complex, large in scale and scope, and located in a challenging urban/industrial environment. Uncertainties exist in many areas, including model predictions of long-term effectiveness, ability to achieve background contaminant concentrations in an urban environment, and the timing and future results of upland source control in numerous locations along the LDW. There is also uncertainty in the relationship between sediment cleanup actions and reductions in fish/shellfish tissue contaminant concentrations, accurate estimation of dredging volumes and cleanup costs, and projections of the time needed to implement the cleanup.

A report by the National Research Council (NRC 2007) on sediment cleanups at large Superfund sites identifies similar challenges at sites 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:

> *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 general, adaptive management should include the following steps:

1) Continue complementary coordinated source control efforts to reduce contaminant loadings to the site, allow cleanups to proceed on schedule, and increase the likelihood of achieving predicted long-term contaminant concentrations.

2) Use the RALs described above to identify the areas for active remediation. These include the most contaminated areas, which will provide the fastest incremental risk reduction.

3) Identify interim goals to be achieved following active remediation and used as benchmarks for evaluating progress toward achieving the RAOs. These goals would be based on current knowledge and predictive modeling. Monitoring data would be evaluated in light of these goals.

4) Complete the early predesign investigations identified in this memorandum to add confidence about technology performance and expedite the implementation of the active cleanup.

5) Implement a comprehensive community outreach and education program to limit risks to people who consume resident fish/shellfish from the LDW.

6) Complete the remedial design studies and implement the baseline monitoring program. Complete the remedial design engineering with location-specific technology assignments based on design-level data and analyses.

7) During remedial design, develop specific contingency measures that would be implemented should the monitoring data show that interim goals are not being achieved for MNR and ENR/*in situ* treatment areas due to failure of remedy components to perform as anticipated.

8) Complete active remediation in areas where surface sediment concentrations exceed the RALs, using the technologies described in Section 2.2.

9) Use design and construction monitoring data and long-term monitoring data to build on baseline data, evaluate how the system is responding, and verify that cleanup objectives have been achieved in dredged or capped areas.

10) Monitor progress in natural recovery areas.

11) Conduct 5-year reviews following the completion of active remediation to assess whether contingency actions are needed in natural recovery areas and to assess the effectiveness of caps and ENR/*in situ* treatment or the need for additional maintenance. The first 5-year review following active remediation would assess achievement of the interim goals and progress toward achieving the RAOs.

12) Integrate into the 5-year reviews a comprehensive review of seafood consumption advisories, source control status, overall waterway health, and the potential need for implementation of contingency actions.

13) Establish funding commitments to implement any needed adaptive management and contingency actions.

3.0 Performance of the Key Elements

The key elements described in Section 2 can be the foundation for a site-wide remedy for the LDW. Figure 1 illustrates, for example, a remedial technology footprint for these combined elements. Table 2 summarizes the estimated technology application areas relative to the total remediation footprint of 331 acres (29 acres of early action areas [EAAs], 180 acres of area of potential concern 1 [AOPC 1], and 122 acres of AOPC 2).

In summary, a total of 137 acres would be actively remediated by a combination of dredging, capping, and ENR with *in situ* treatment. This is in addition to the 29 acres of EAAs. Twenty acres exceeding the SQS for non-human health risk-driver contaminants would be remediated by MNR. As discussed below, natural recovery would continue to play a role in incrementally reducing contaminant concentrations across the site until the system stabilizes in response to lateral and upstream inputs (which may continue to decrease due to ongoing source control efforts).

ENR or ENR with *in situ* treatment would be applied to 65 acres, considering location-specific design analyses. ENR with *in situ* treatment is emphasized over conventional ENR to reduce contaminant bioavailability. This emphasis is acknowledged in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Model Toxics Control Act (MTCA) evaluation below. Note from Table 2 that, of the 65 acres potentially subject to ENR with *in situ* treatment, approximately 16 would be located in areas prone to scour (Recovery Category 1 areas as defined in the Draft Final FS). ENR with *in situ* treatment would be implemented in these areas when coupled with innovative scour mitigation technologies to increase reliability. This approach would be supported by the predesign investigations discussed in Section 2.3.

3.1 Achievement of Remedial Action Objectives

Performance of the combined elements described in Section 2 is, in part, based on reducing contaminant concentrations (and therefore risks) over time. As with alternatives in the Draft Final FS, contaminant reductions in surface sediment occur as a result of both implementing the active remedial technologies (i.e., dredging, capping, ENR) and natural recovery over time. After construction, any additional reductions in surface sediment contaminant concentrations occur only from natural recovery processes. The bed composition model (BCM) developed in the Draft Final FS for estimating contaminant concentration reductions from both mechanisms was used to evaluate the performance of the combined key elements described in Section 2. Table A1 in the attachment contains BCM-predicted concentrations of the human health risk-driver contaminants as well as outcomes for SMS risk drivers if these combined key elements were to be implemented. Tables A2, A3, and A4 present risk estimates that are based on these concentrations for the exposure scenarios developed in the Remedial Investigation.

Figure 2 summarizes estimated reductions in the site-wide spatially-weighted average concentrations (SWACs) for total PCBs, arsenic, cPAHs, and dioxins/furans in surface sediment as percentages of the baseline values (i.e., concentrations before completion of the EAAs). After construction, both total PCBs and dioxin/furan concentrations are reduced by over 70% by active remediation (the bioavailable fractions of these contaminants are expected to be further reduced in areas receiving *in situ* treatment). Additional incremental reductions in surface sediment concentrations of total PCBs and dioxins/furans are predicted to occur as a result of natural recovery either during or following construction compared to the reduction from active remediation. The majority of arsenic concentration reduction also occurs as a result of active remediation. Natural recovery plays a greater role in the reduction of cPAH concentrations than it does for the other three risk drivers.

Figure 3 summarizes the predicted number of years to achieve risk reduction outcomes pertinent to each RAO, and compares these outcomes to the Draft Final FS alternatives. For RAO 1, future excess cancer risks were estimated from resident seafood tissue total PCB concentrations predicted using the food web model with the anticipated total PCB concentrations in surface sediment.[3] Significant reductions in the total PCB SWAC and the associated risks are achieved for RAO 1 immediately after construction.

For any cleanup in the LDW, remedial construction is expected to increase the export of contaminants downstream and also cause contaminant concentrations to persist at elevated levels in resident fish/shellfish tissue until after active remediation is complete. It is important to remember that actual risk reduction for people who consume resident seafood from the LDW can only occur after remedial construction is complete. Thus, the comparatively short construction time frame of the combined elements is a key advantage in making progress toward achieving RAO 1. The estimated excess cancer risks for total PCBs corresponding to the Adult Tribal and Adult Asian Pacific Islander (API) seafood consumption scenarios are in the 10^{-4} risk range (and 10^{-5} risk range for Child Tribal RME) after construction and are not predicted to significantly decrease further with time. The long-term model-predicted SWAC for total PCBs (about 45 to 50 µg/kg dw) is predicted to be achieved about 10 years after construction with continued natural recovery processes. However, this additional decrease in the SWAC is not expected to result in significantly lower risks. It is important to note that the seafood consumption risk estimates do not reflect the incremental benefits of reducing contaminant bioavailability by *in situ* treatment.

For RAO 2, results are predicted to achieve acceptable levels of human health direct contact risks through active remediation. Following active remediation, the cumulative excess cancer

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3 It was not possible to estimate future human health risks from seafood consumption for arsenic or cPAHs because the relationships between clam tissue and these risk-driver concentrations were too uncertain to develop quantitative risks. It was not possible to estimate future human health risks from seafood consumption for dioxins/furans because there were no tissue data available from the LDW for these contaminants.

risks for all direct contact scenarios will be less than 1×10^{-5} and non-cancer hazard quotients will be less than 1. Excess cancer risks for PCBs and dioxins/furans will be equal to or less than 1×10^{-6} following construction. As with all other remedial alternatives, excess cancer risks for arsenic will be less than 1×10^{-5} (cancer risks of 1×10^{-6} are below natural background concentrations). Excess cancer risks for cPAHs in all exposure areas (except one beach) are expected to be at 1×10^{-6} following construction.

Although the design criterion was to achieve the SQS for SMS chemicals within 10 years after construction, RAO 3 is predicted to be achieved immediately after construction (assuming natural recovery occurs during construction). In the event that natural recovery is progressing more slowly than predicted (e.g., not on target to achieve the SQS within 10 years after construction), contingency actions may be necessary.

Lastly, the preliminary remediation goal for protection of the river otter and other ecological receptors (RAO 4) is predicted to be achieved by the time construction is completed.

Figure 3 also compares the time to achieve RAOs for the combined elements to those obtained by the remedial alternatives in the Draft Final FS. Advantages of the combined elements are evident from this chart as follows:

- One of the shortest construction time frames (5 years).
- The quickest aggregate reduction of risks from total PCBs to humans consuming resident seafood (RAO 1).
- The same RAO 2 outcomes as Alternatives 3 through 6.
- RAOs 3 and 4 achieved immediately after construction (however, an additional 1 to 2 years of recovery in fish/shellfish tissue contaminant concentrations may be required following construction completion to reduce the effects associated with dredging operations and fully achieve RAO 4).

3.2 CERCLA Evaluation – Comparative Analysis

A brief summary of the CERCLA evaluation for the combined key elements and how they compare to the remedial alternatives developed for the Draft Final FS is provided below for illustrative purposes. Table A5 presents the comparative results.

Threshold Criteria

Overall Protection of Human Health and the Environment: The combined key elements achieve overall protection of human health and the environment by removing a large volume of the most contaminated sediments (estimated at 620,000 cubic yards [cy]), yet can be constructed quickly (5 years) by allowing capping, ENR, *in situ* treatment, and MNR remediation of an estimated 85 acres of moderately to less contaminated areas. This approach reduces both short-term impacts and the bioavailability of residual contamination. Subsurface contamination remaining in a relatively small portion of these areas could be re-exposed by natural or mechanical disturbances (e.g., scour). However, application of ENR and *in situ* treatment in these areas would incorporate scour mitigation measures, as needed, to reduce re-exposure potential. MNR applications are limited to non-human health risk drivers. As with all remedial alternatives presented in the Draft Final FS, institutional controls are required to fully achieve protectiveness because of the likelihood that some cleanup levels and applicable or relevant and appropriate requirements (ARARs) cannot be achieved.

Compliance With or Waiver of ARARs: None of the remedial alternatives presented in the Draft Final FS are expected to comply with all surface water quality standards, or to achieve the natural background sediment concentrations required under MTCA (for risk-based threshold concentrations [RBTCs] below background). The combined elements are no different. Surface water quality and MTCA ARAR waivers are likely to eventually be necessary for any cleanup of the LDW.

Balancing Criteria

Long-term Effectiveness: The key elements, if used in combination, actively remediate 137 acres in addition to the 29 acres of the EAAs. The potential for re-exposure is considered low because scour mitigation technologies would be used, where warranted, to prevent scour-induced re-exposure of contaminated sediment. A large area (119 acres) would require monitoring and maintenance (99 acres of capping and ENR/*in situ* treatment; 20 acres of MNR). Monitoring, maintenance, and institutional controls combined with contingency actions are collectively considered adequate and reliable for this purpose. Overall, the combined elements are ranked similar to Alternatives 4C, 4R, 5C, and 6C for this criterion, although the greater use of *in situ* treatment in the combined elements may result in improved long-term effectiveness.

Reduction of Toxicity, Mobility, or Volume through Treatment: *In situ* treatment would figure prominently in the combined elements approach. An estimated 65 acres would be remediated by a combination of ENR and *in situ* treatment, with an emphasis on the latter. Through the use of activated carbon,[4] hydrophobic contaminants bind to the activated carbon, making them less available for uptake by organisms (i.e., reduced bioavailability). This is a greater use of *in situ* treatment than any of the alternatives, so the combined elements rank high for this criterion.

Short-term Effectiveness: Impacts to workers, the community, and the environment from construction are relatively low based on the 5-year construction period. The estimated removal and handling volume (620,000 cy) is less than Alternatives 4C and 5C, reflecting fewer impacts to the community and the environment associated with dredged materials management (e.g., export of chemicals released from dredging and air, noise, and traffic impacts from material handling and transportation activities).

The time to achieve significant risk reduction milestones is predicted to be shortest, in the aggregate, for the combined elements (Figure 3). Uncertainty associated with MNR is limited to non-human health risk drivers and to areas that are expected to comply with the SMS by achieving SQS levels within 10 years after construction. The combined elements rank the highest for this criterion compared to the remedial alternatives in the Draft Final FS.

Implementability: The construction period is estimated to be 5 years, which is on the low end of the construction times for the range of remedial alternatives considered in the FS. The potential for difficulties and delays is moderate because of the combination of technologies used; this potential is further reduced through the predesign studies recommended in this memorandum. Additional contingency actions may potentially be needed to achieve low RALs after dredging. Contingency actions will be implemented in portions of the ENR/*in situ*

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[4] Activated carbon is the most common material used for *in situ* treatment of hydrophobic organic compounds such as PCBs, cPAHs, and dioxins/furans.

treatment and MNR areas as necessary. Overall, the implementability issues are considered manageable and the combined elements rank high for this criterion, similar to Alternatives 1, 4C, 4R, and 5C evaluated in the FS.

Costs: The costs that result from utilizing these key elements in combination are estimated at ~$260 million, not including any costs associated with the predesign studies or EAA remediation.

3.3 MTCA Disproportionate Cost Analysis

The structure of the MTCA disproportionate cost analysis (DCA) for cleanup of the LDW was modified by Ecology during the Draft Final FS comment resolution period. Figure 4 charts the resulting remedial alternative benefits versus cost. The key elements that this memorandum describes, when combined, are positioned in the upper left-hand corner of the chart, a location that reflects comparatively high benefits for a comparatively low cost. Values for the performance metrics used in the DCA were quantified for the combined elements and incorporated into the updated DCA rankings (see Table A6).

3.4 Other Performance Considerations

Certainty

The combined key elements reduce uncertainty associated with remedy performance by:

- Targeting the contaminants that drive seafood consumption risks for active cleanup, creating greater certainty that risk reduction will be achieved early in the process.
- Dredging the most contaminated areas and using activated carbon for *in situ* treatment of less contaminated areas, resulting in fewer water column disturbances for shorter periods of time. The use of carbon reduces contaminant bioavailability both initially and into the future.
- Using predesign studies to refine site-specific technology assignments to ensure that the right technology is being applied to the right area.
- Providing comprehensive monitoring and response plans to ensure that the remedy achieves its long-term goals by measuring progress and establishing a framework for timely and thoughtful course corrections as needed.

Waterway Users

The key elements, when combined, would benefit all waterway users. Addressing contaminants associated with human health risks as the highest priority as quickly as possible helps reduce risks to Tribal, community, and recreational fishers. Design flexibility and shorter construction time frames are elements that preserve and enhance the beneficial uses and ecological services the waterway provides to all users, and reduce construction impacts to residents, businesses, and the waterway's ecology. Shorter construction time frames provide greater certainty concerning the timing of cleanup completion. This should provide greater confidence in future planning. Finally, completing key predesign studies early in the process is also in everyone's interest to move the cleanup toward completion as rapidly as possible.

Community Outreach and Education

Complementing a thorough cleanup, another key element is developing a robust community outreach and education program as part of the program of institutional controls, necessary for any remedy. The combined elements described in this memorandum are expected to achieve the same level of human health risk reduction as the FS alternatives but in a shorter time frame. Seafood consumption risks are expected to remain elevated during dredging and general construction, and construction activities will impact businesses, the community and tribal fishers. As a result, a greater level of public outreach and education may be necessary during the construction phase of any remedy. The shorter the construction time, the shorter the period when reliance on these construction-phase informational activities will be needed. A concerted effort to engage all elements of the community in continuing risk reduction strategies post-construction will be needed as well, regardless of the alternative selected, and will be integral to institutional control planning and implementation. These types of activities are required with any FS option and are not substitutes for cleanup, but rather components of the cleanup solution.

4.0 Conclusions

LDWG has identified a number of key elements from the Draft Final FS that, when combined, are responsive to required evaluation criteria and key stakeholder comments. These key elements draw from the most effective features of the remedial alternatives for the LDW that were presented in the Draft Final FS and include new ideas based on EPA, Ecology, and stakeholder feedback. In addition, LDWG has identified predesign elements that could be conducted concurrently to help support a timely implementation of the final remedy, whichever is ultimately selected.

The combined element approach should achieve the following benefits:

1) **Focuses on reducing human health risks as quickly as possible.** The optimized RALs, in conjunction with a combined technology approach to cleanup, reduce risks to human health and the environment quickly and efficiently in comparison to the remedial alternatives presented in the Draft Final FS.

2) **Provides faster risk reduction and reduces construction impacts to the community and the environment.** Many of the key risk reduction benchmarks are achieved during a total construction period of 5 years (see Figure 3). Impacts to the community from management of dredged materials are at the low end of the range of remedial alternatives. Predesign studies will help accelerate the implementation and reliability of the cleanup actions.

3) **Reduces the time required to achieve the RAOs.** The relative rankings for the CERCLA balancing criteria are as high as or higher than those for the other remedial alternatives in balancing short-term risks with long-term protectiveness. The total weighted benefits evaluated in the MTCA DCA compare favorably with the highest scored remedial alternatives from the Draft Final FS.

4) **Prioritizes dredging or capping in hot-spot areas, provides flexibility in technology application rules, provides more certainty, and ensures the best solution is applied to remaining areas.** Upper concentration limits for ENR and *in*

situ treatment ensure that the more contaminated areas are prioritized for dredging and/or capping. Data from predesign investigations would be used to improve the technical basis for engineering specific remedial technologies for location-specific conditions (e.g., addition of activated carbon for *in situ* treatment and ENR applications) such that remedy reliability is enhanced. MNR would be used to reduce contaminant concentrations that present risks to the benthic community in a time frame consistent with MTCA and the SMS (i.e., within 10 years following construction). After active remediation is complete, continued source control efforts and site-wide natural recovery processes are expected to continue reducing surface sediment contaminant concentrations over time.

5) **Includes a broad monitoring and community outreach/education program consisting of extensive LDW-wide monitoring, periodic reviews, seafood consumption advisories, public outreach and education, and tracking to address remaining risks to the community following cleanup.** This range of activities is key to any selected approach. The monitoring program is of sufficient scope to enable early adjustments to the remedy as data become available.

6) **Benefits all waterway users by prioritizing human health risk reduction, optimizing technology assignments, and reducing the construction time.**

Finally, effective and thorough source control is a key component to remediation success. The key elements described in this memorandum can be well-integrated with local and state governments' ongoing efforts to improve coordination, define gaps, and implement source control work throughout the Lower Duwamish basin, ensuring timely implementation and achieving long-term goals.

5.0 References

NRC 2007. *Sediment Dredging at Superfund Megasites – Assessing the Effectiveness*. National Research Council of the National Academies. The National Academies Press 500 5th St, NW Washington D.C., 20001. 2007.

Ecology 2009. *Contaminant Loading to the Lower Duwamish Waterway from Suspended Sediment in the Green River.* Washington State Department of Ecology. Publication No. 09-03-028. November 2009.

ECOSS 2011. *Memorandum: Lower Duwamish Waterway Outreach Summary.* Prepared for EnviroIssues. Prepared by Environmental Coalition of South Seattle. January 31, 2011. Addendum February 24, 2011.

Figures and Tables

Table 1 Remedial Action Levels and Technology Application Limits

Table 2 Scope of Combined Elements

Figure 1 Technology Assignments for a Combined Elements Approach

Figure 2 Reduction of Total PCB, Arsenic, cPAH, and Dioxin/Furan SWACs by Active Remediation and Natural Recovery

Figure 3 Time to Achieve RAOs – Combined Elements Compared to FS Alternatives

Figure 4 MTCA Benefits Score vs. Cost - Combined Elements Compared to FS Alternatives

Attachment – Detailed Model Output and CERCLA/MTCA Rankings

Table A1 BCM Output – Predicted Post-construction Arsenic, total PCBs, cPAH, and Dioxin/Furan SWACs and SMS Exceedances

Table A2 Seafood Consumption Cancer and Non-cancer Risks for Human Health Scenarios and River Otter Risks over Time

Table A3 Cumulative Excess Cancer Risks for Human Health Direct Contact

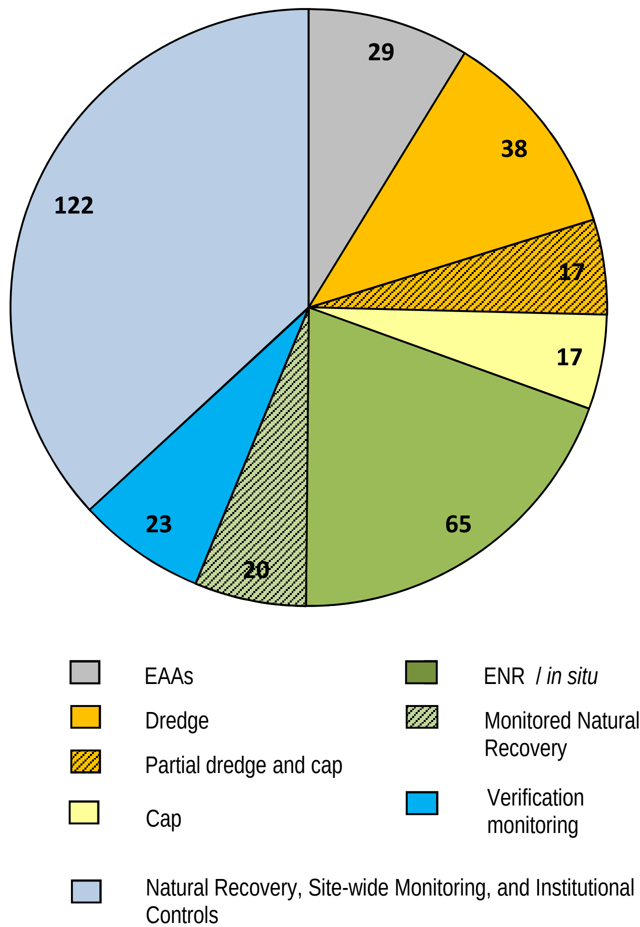
Table A4 Individual Risk Driver Excess Cancer Risks for Human Health Direct Contact

Table A5 Comparative Evaluation and Relative Ranking of Remedial Alternatives

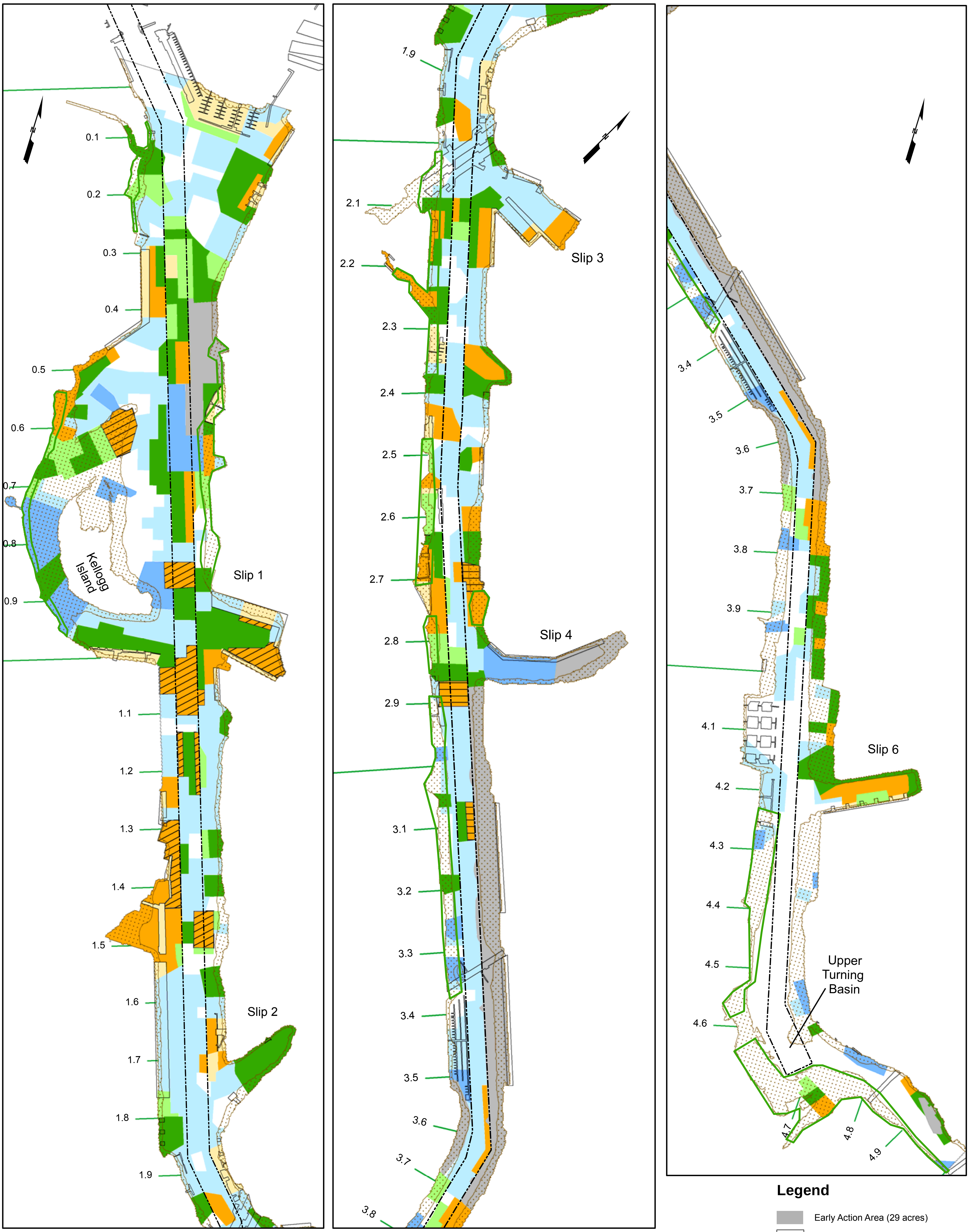
Table A6 MTCA Disproportionate Cost Analysis and Ranking Spreadsheet

Table 2 Scope of Combined Elements

Early Action Areas (acres)		29
Actively Remediated Area (acre)	Dredge	38
	Partial Dredge and Cap	17
	Cap	17
	ENR / *in situ* treatment	65
Passively Remediated Area (acre)	MNR	20
	Verification Monitoring	23
Other Outcomes of Interest	Active/Passive/Total Managed Area (acres)	137/43/180
	Natural Recovery, Site-wide Monitoring, and Institutional Controls (acres)	122
	Dredge-cut Prism Volume (cy)	470,000
	Performance Contingency Volume (cy)	620,000
	Construction Period (years)	5
	MNR located in Category 1 areas (acres)	0
	ENR / *in situ* located in berthing areas (acres)	4
	ENR / *in situ* located in areas prone to scour (acres)	16



Note: numbers in pie charts represent acres; total area is 331 acres comprised of EAAs and AOPCs 1 and 2. Total FS study area is 441 acres.



Notes:
1. The total FS study area is 441 acres.
2. Technology assignments are approximate and may change based on additional data.
3. RALs shown below were considered in the definition of the AOPCs. AOPC 2 excludes the footprint of AOPC 1.
4. AOPC = Area of Potential Concern.

AOPC	Remedial Action Levels (RALs)				
	Total PCBs µg/kg dw	cPAHs µg TEQ/kg dw	Dioxins/ Furans ng TEQ/kg dw	Arsenic mg/kg dw	Benthic SMS 41 Chemicals
1	240[a]	1,000 (site-wide), 900 (intertidal)	25	57 (site-wide), 28 (intertidal)	SQS
2	100	Same	15	15	Same

a. Carbon-normalized value will be used during remedy design (12 mg/kg oc).

Technology Assignment

AOPC 1
- Dredge (38 acres)
- Partial Dredge and Cap (17 acres)
- Cap (17 acres)
- ENR/*in situ* Treatment (65 acres)
- Monitored Natural Recovery (20 acres)
- Verification Monitoring Area (23 acres)

- AOPC 2 Outside of AOPC 1 (Institutional Controls, Natural Recovery, and Site-wide Monitoring) (122 acres)
- Remaining Study Area (Institutional Controls and Site-wide Monitoring) (110 acres)

0 200 400 800 Feet

Legend
- Early Action Area (29 acres)
- Overwater Structure
- Beach Play Area
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

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AECOM Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

Lower Duwamish Waterway
Key Elements Memo
60150279-9.8

DATE: 07/29/11 | DWRN:MVI/sea | Revision: 0

Technology Assignments for Combined Elements

FIGURE 1

Figure 2 Reduction of Total PCB, Arsenic, cPAH, and Dioxin/Furan SWACs by Active Remediation and Natural Recovery

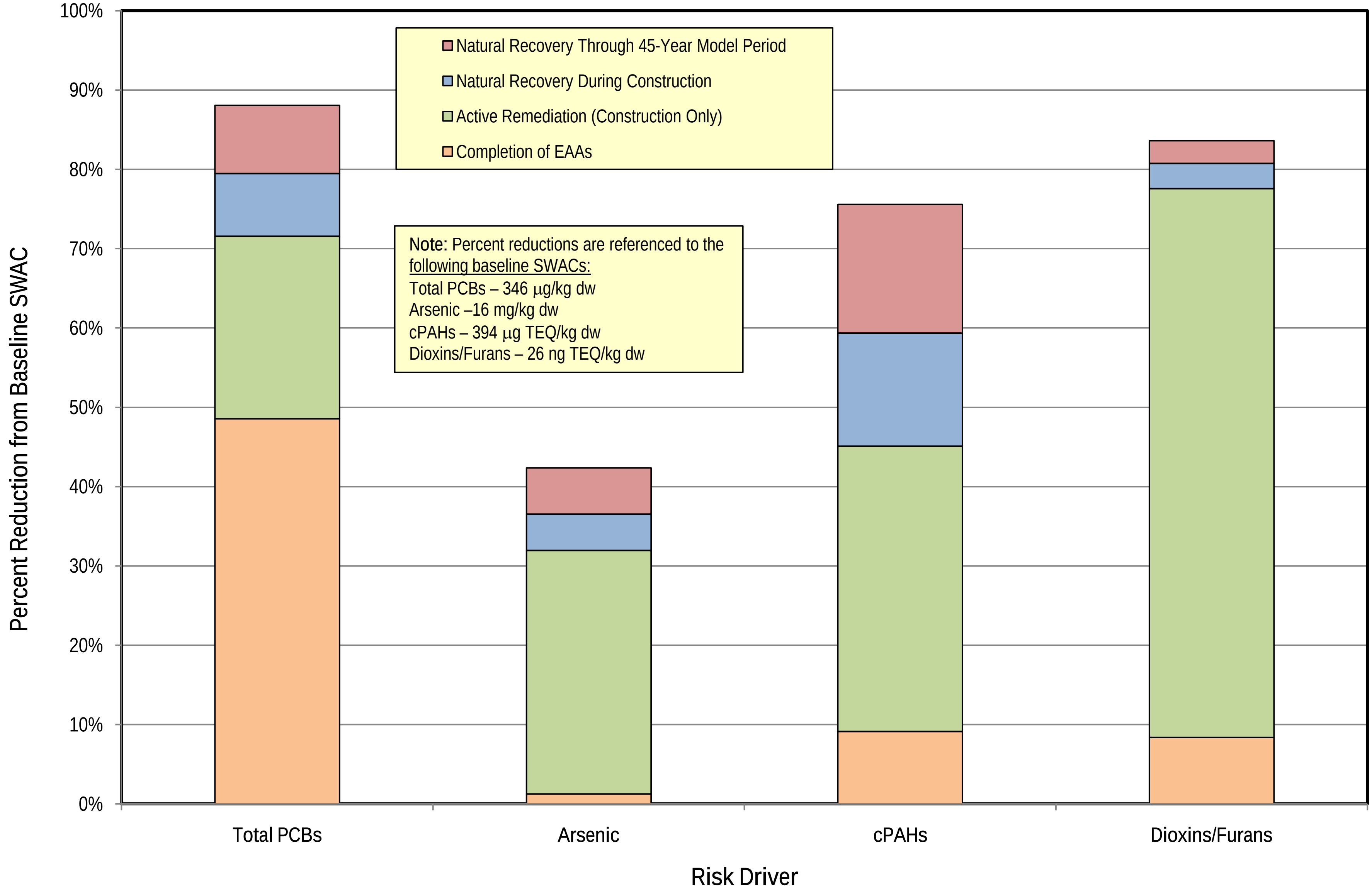
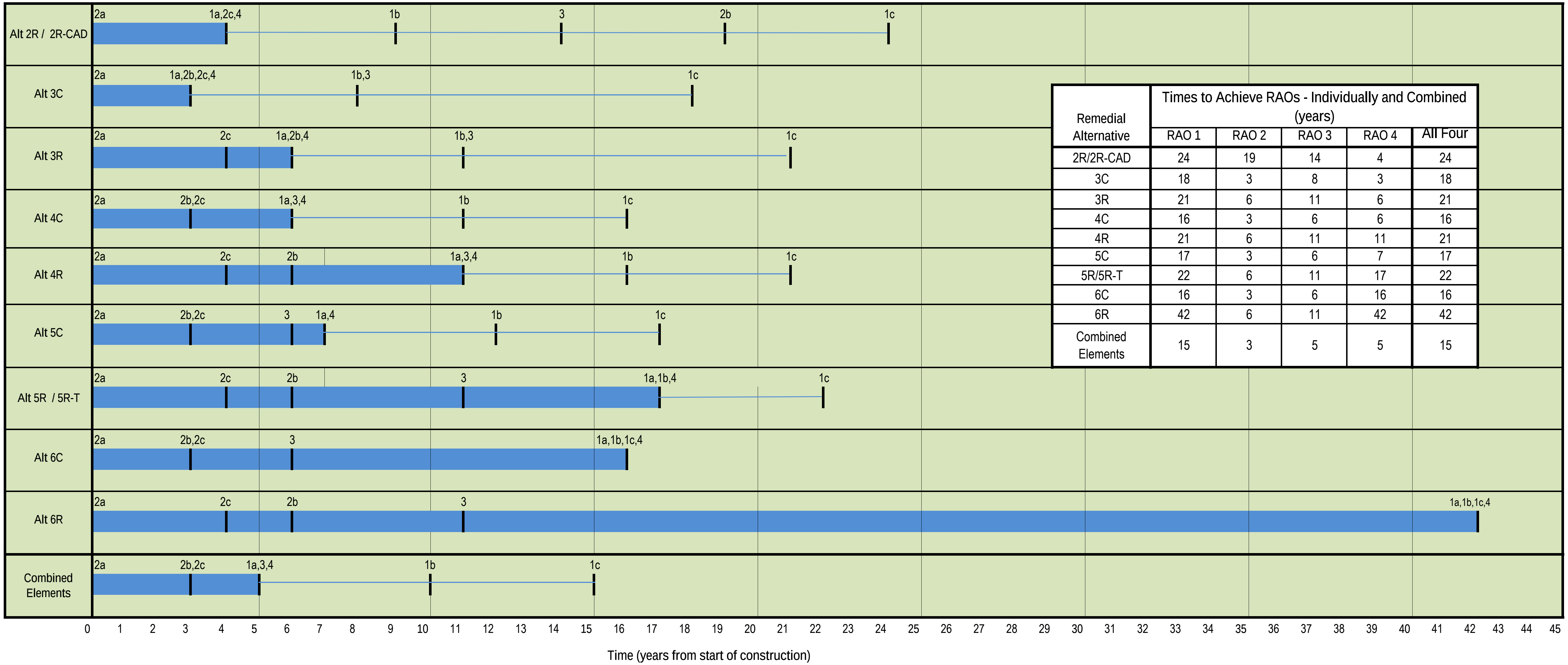


Figure 3 Time to Achieve RAOs – Combined Elements Compared to FS Alternatives



Remedial Alternative	Times to Achieve RAOs - Individually and Combined (years)				
	RAO 1	RAO 2	RAO 3	RAO 4	All Four
2R/2R-CAD	24	19	14	4	24
3C	18	3	8	3	18
3R	21	6	11	6	21
4C	16	3	6	6	16
4R	21	6	11	11	21
5C	17	3	6	7	17
5R/5R-T	22	6	11	17	22
6C	16	3	6	16	16
6R	42	6	11	42	42
Combined Elements	15	3	5	5	15

Construction Period

Post-construction natural recovery period

2b — Year the risk reduction metric is achieved

RAO	Chart Symbol	Metric(s)
1	1a	10^{-4} magnitude risk for Adult Tribal, Child Tribal and Adult API RME seafood consumption scenarios (only total PCBs)
	1b	10^{-5} magnitude risk for Child Tribal RME seafood consumption scenario (only total PCBs)
	1c	Total PCBs and dioxin/furans reach long-term model-predicted ranges of site-wide SWACs
3	3	SQS (≥ 98% of LDW area below SQS)
4	4	HQ <1 (River Otter)

RAO	Chart Symbol	Metric(s)
2	2a	≤ 1 x 10^{-5} cumulative direct contact risk and HQ <1 in all exposure areas
		≤ 1 x 10^{-6} direct contact risk from total PCBs in all areas
		≤ 1 x 10^{-5} and > 1 x 10^{-6} direct contact risk from arsenic in all areas
	2b	< 1 x 10^{-6} direct contact risk from dioxins/furans in all areas
		≤ 1 x 10^{-6} direct contact risk from cPAHs in all areas except Beach 3
		MTCA unrestricted cleanup level (≤140 µg TEQ/kg dw) for cPAHs at beaches except Beach 3
	2c	Arsenic reaches long-term model-predicted ranges of site-wide SWACs

Notes:

1. None of the alternatives are predicted to achieve a non-cancer HQ below 1 for three RME scenarios (see Table 9-7b of Final FS for details).
2. None of the alternatives are expected to achieve sediment PRGs that are based on natural background: total PCBs and dioxins/furans - seafood consumption (RAO 1); arsenic - direct contact all scenarios (RAO 2).
3. Fish/shellfish tissue total PCB concentrations are expected to remain elevated for up to 2 years as a result of construction impacts (e.g., sediment resuspension). This applies to RAOs 1 and 4.

API = asian and pacific islander; C = combined; FS = feasibility study; HQ = hazard quotient; LDW = Lower Duwamish Waterway; PRG = preliminary remediation goal; R = removal; R-T = removal with treatment; RAO = remedial action objective; RME = reasonable maximum exposure; SQS = sediment quality standard; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent

Figure 4 MTCA Benefits Score vs. Cost
Final FS Alternatives and Combined Elements

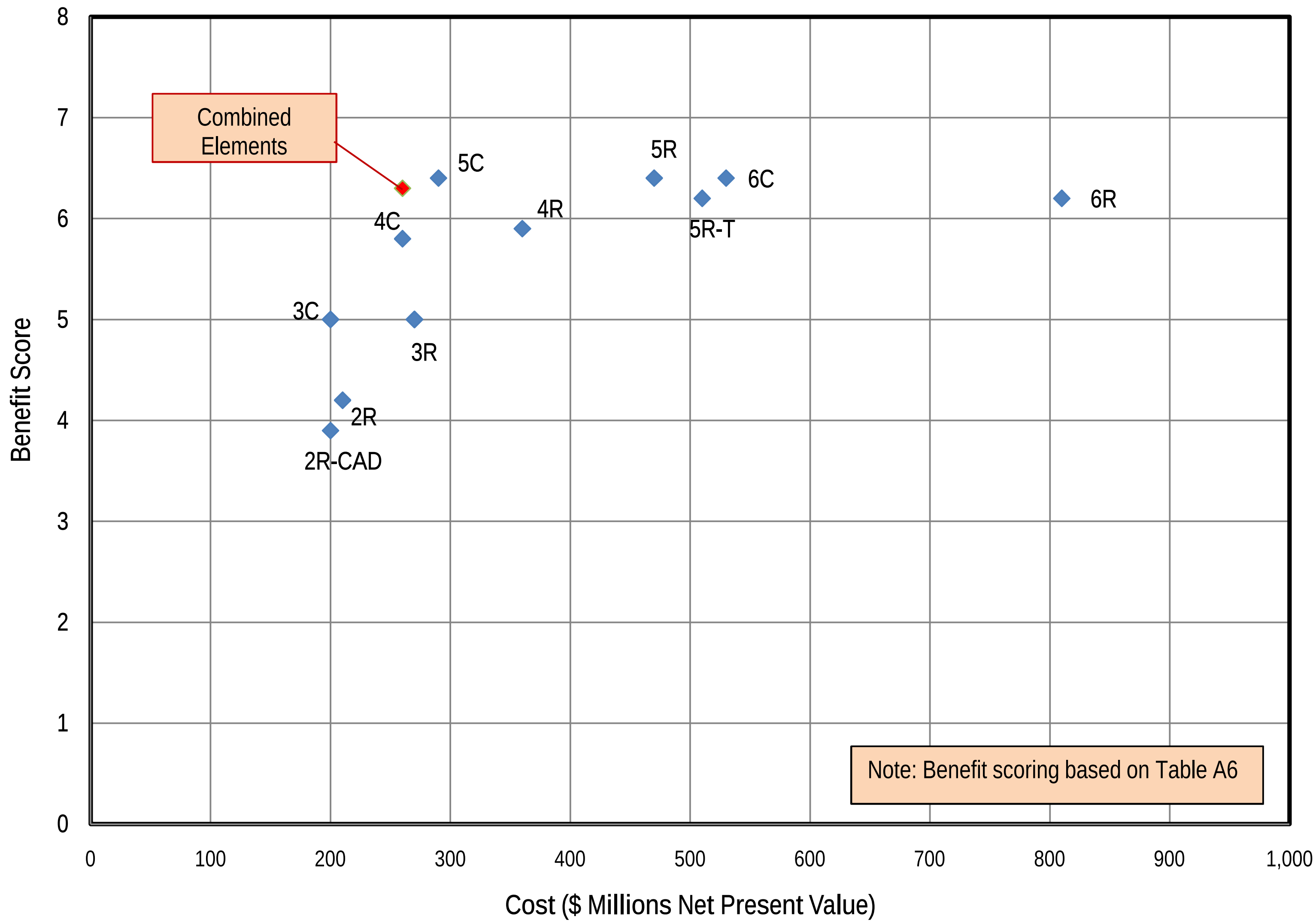


Table A1 BCM Output – Predicted Post-construction Arsenic, Total PCB, cPAH, and Dioxin/Furan SWACs and SMS Exceedances

Site-wide – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	16	10	10	9.3	9.2	9.2	9.2	9.1	9.1	9.1
Total PCBs (µg/kg dw)	178	71	56	49	46	45	44	43	43	41
cPAHs (µg TEQ/kg dw)	358	160	131	111	106	103	106	103	103	96
Dioxins/Furans (ng TEQ/kg dw)	24	5.0	4.7	4.4	4.4	4.4	4.4	4.4	4.4	4.3

Tribal Clamming – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	13	9.5	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1
Total PCBs (µg/kg dw)	195	59	52	48	46	45	45	44	44	43
cPAHs (µg TEQ/kg dw)	296	130	118	107	106	105	106	103	105	99
Dioxins/Furans (ng TEQ/kg dw)	30	5.1	4.8	4.5	4.4	4.4	4.4	4.4	4.4	4.3

Total Beach Play Area – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	9.1	9.5	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Total PCBs (µg/kg dw)	275	54	49	45	44	44	45	44	44	42
cPAHs (µg TEQ/kg dw)	308	143	131	116	118	118	123	117	118	109
Dioxins/Furans (ng TEQ/kg dw)	14	4.8	4.7	4.5	4.6	4.6	4.6	4.6	4.6	4.5

Beach 1 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	8.9	8.6	8.5	8.9	9.0	9.1	9.1	9.1	9.1	9.1
Total PCBs (µg/kg dw)	51	47	46	45	43	43	43	44	44	43
cPAHs (µg TEQ/kg dw)	397	111	115	111	106	108	107	113	115	108
Dioxins/Furans (ng TEQ/kg dw)	5.3	4.6	4.6	4.5	4.4	4.5	4.4	4.5	4.5	4.5

Beach 2 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	13	10.7	10.1	9.7	9.4	9.3	9.2	9.2	9.1	9.1
Total PCBs (µg/kg dw)	278	85	69	57	47	44	43	41	40	39
cPAHs (µg TEQ/kg dw)	752	135	118	106	93	90	89	88	87	84
Dioxins/Furans (ng TEQ/kg dw)	23	7.1	6.1	5.2	4.8	4.6	4.5	4.4	4.3	4.2

Beach 3 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	10.5	10.3	10.0	9.8	9.8	9.8	9.8	9.7	9.7	9.6
Total PCBs (µg/kg dw)	104	70	69	62	62	63	65	65	65	60
cPAHs (µg TEQ/kg dw)	381	302	276	234	237	239	242	240	239	216
Dioxins/Furans (ng TEQ/kg dw)	7.2	5.7	5.9	5.6	5.7	5.8	6.0	5.9	5.9	5.6

Beach 4 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	7.5	9.4	9.2	9.2	9.1	9.1	9.1	9.1	9.1	9.1
Total PCBs (µg/kg dw)	1099	59	48	43	43	43	41	42	43	41
cPAHs (µg TEQ/kg dw)	382	138	120	104	108	109	99	107	112	99
Dioxins/Furans (ng TEQ/kg dw)	47	4.6	4.6	4.3	4.5	4.5	4.4	4.4	4.5	4.4

Beach 5 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	9.0	8.9	8.8	8.8	8.8	8.7	8.7	8.8	8.8	8.7
Total PCBs (µg/kg dw)	123	58	53	52	52	51	52	49	50	50
cPAHs (µg TEQ/kg dw)	385	116	104	99	100	99	100	96	98	94
Dioxins/Furans (ng TEQ/kg dw)	10	4.0	4.2	4.1	4.2	4.2	4.3	4.2	4.2	4.2

Beach 6 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	11.5	10.0	9.3	9.2	9.1	9.1	9.1	9.1	9.1	9.0
Total PCBs (µg/kg dw)	448	60	43	41	39	39	39	38	38	37
cPAHs (µg TEQ/kg dw)	531	140	96	90	87	86	87	83	84	81
Dioxins/Furans (ng TEQ/kg dw)	8.3	4.0	4.1	4.1	4.1	4.1	4.2	4.1	4.2	4.1

Beach 7 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	9.1	9.0	9.1	9.1	9.0	9.1	9.1	9.1	9.1	9.1
Total PCBs (µg/kg dw)	46	41	42	40	41	41	41	41	41	40
cPAHs (µg TEQ/kg dw)	97	96	97	98	97	97	96	96	95	93
Dioxins/Furans (ng TEQ/kg dw)	4.5	4.2	4.3	4.2	4.3	4.3	4.3	4.4	4.4	4.3

Beach 8 – Time from Beginning of Construction (years)

Risk Driver	0[a]	5[b]	10	15	20	25	30	35	40	45
Arsenic (mg/kg dw)	8.0	9.1	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Total PCBs (µg/kg dw)	49	38	35	35	35	35	35	35	35	35
cPAHs (µg TEQ/kg dw)	184	84	74	72	73	73	72	71	71	70
Dioxins/Furans (ng TEQ/kg dw)	3.8	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

Site-wide – Time from Beginning of Construction (years)

Other SMS Risk Drivers	0[a]		5[b]		10		15		20		25		30		35		40		45	
	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS	% of Stations < SQS
CSL	95%	96%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%
SQS	84%	82%	99%	99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%	>99%

(Green shading:) Predicted percentage of baseline stations or LDW surface area below SQS is ≥ 98%

Notes:
1. BCM predictions use base case STM outputs revised June 2010.
2. Total active area = 137 acres, BCM model area = 430 acres, and FS study area = 441 acres
3. Arsenic BCM inputs (mg/kg dw): upstream 9, lateral 13, and post-remedy bed sediment replacement value 10 (AOPC 1).
4. Total PCB BCM inputs (µg/kg dw): upstream 35, lateral 300, and post-remedy bed sediment replacement value 60 (AOPC 1).
5. cPAH BCM inputs (µg TEQ/kg dw): upstream 70, lateral 1,400, and post-remedy bed sediment replacement value 140 (AOPC 1).
6. Dioxin/furan BCM inputs (ng TEQ/kg dw): upstream 4, lateral 20, and post-remedy bed sediment replacement value 4 (AOPC 1).
7. The % of LDW area below SMS criteria is calculated by dividing the polygon-derived areas associated with predicted exceedances by the total area of the LDW (441 acres).
8. The % of stations below SMS criteria is calculated by dividing the predicted number of station exceedances by the number of FS baseline stations (n = 1,395 points).

a Estimated conditions following completion of the EAAs. Also, year 0 is the assumed start of construction and start of the BCM.
b The construction period is estimated at 5 years.
AOPC = area of potential concern; BCM = bed composition model; FS = feasibility study; LDW = Lower Duwamish Waterway; SMS = sediment management standards; STM = sediment transport model; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent

Table A2 Seafood Consumption Excess Cancer and Non-Cancer Risks for Human Health RME Scenarios and River Otter Risks Over Time

Combined Elements	Adult Tribal RME (Tulalip data)									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Excess Cancer Risk	5E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04
Non-Cancer Risk (HQ)	13	6	5	5	5	5	5	5	5	4

Combined Elements	Child Tribal RME (Tulalip data)									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Excess Cancer Risk	1E-04	5E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	3E-05	3E-05
Non-Cancer Risk (HQ)	29	13	11	10	10	10	10	10	10	10

Combined Elements	Adult API RME (Tulalip data)									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Excess Cancer Risk	2E-04	7E-05	6E-05	6E-05	6E-05	5E-05	5E-05	5E-05	5E-05	5E-05
Non-Cancer Risk (HQ)	9	9	4	3	3	3	3	3	3	3

Combined Elements	River Otter LOAEL-based HQ - with Juvenile Fish									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Non-Cancer Risk (HQ)	1.1	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Combined Elements	River Otter LOAEL-based HQ - without Juvenile Fish									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Non-Cancer Risk (HQ)	1.3	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4

Notes:
1. Risks estimated using the food web model (Windward 2010), total PCB SWACs in surface sediment (Table A1), and assumed surface water dissolved total PCB concentrations of 0.6 ng/L.
2. Significant figures are displayed in accordance with the conventions established in the HHRA.

a. Estimated conditions following completion of the EAAs. Also, year 0 is the assumed start of construction and start of the BCM. Risks during construction are assumed to be the same as prior to the start of construction
b. The construction period is estimated at 5 years. Fish/shellfish tissue concentrations are expected to remain elevated in total PCBs for up to 2 years as a result of construction impacts (e.g., sediment resuspension)

10^{-3}
10^{-4}
10^{-5} — Colored cells indicate residual excess cancer risk rounded to the nearest order of magnitude.
HQ >1
HQ ≤1 — Colored cells indicate residual non-cancer hazard quotient.
7E-05 — Red font indicates risk estimate based on the end of construction PCB SWAC.

Table A3 Cumulative Excess Cancer Risks for Human Health RME Direct Contact Scenarios

Combined Elements	Cumulative Excess Cancer Risk									
	Time from Beginning of Construction (years)									
	0 [a]	*5 [b]*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Site-wide Netfishing	6E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Tribal Clamming	1E-05	9E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
Beach 1	8E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06
Beach 2	1E-05	6E-06	5E-06	5E-06	5E-06	5E-06	4E-06	4E-06	4E-06	4E-06
Beach 3	8E-06	7E-06	7E-06	6E-06	6E-06	6E-06	6E-06	6E-06	6E-06	6E-06
Beach 4	9E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06	5E-06
Beach 5	8E-06	5E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06
Beach 6	1E-05	5E-06	5E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06
Beach 7	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06
Beach 8	5E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06	4E-06

Notes:
1. Cumulative excess cancer risks include only the human health risk-drivers (total PCBs, arsenic, cPAHs, and dioxins/furans)
2. Significant figures are displayed in accordance with the conventions established in the HHRA.
a. Estimated conditions following completion of the EAAs. Also, year 0 is the assumed start of construction and start of the BCM.
b. The construction period is estimated at 5 years.

10^{-5}
10^{-6} — Colored cells indicate residual excess cancer risk rounded to the nearest order of magnitude.

API = Asian and Pacific Islander; BCM = bed composition model; cPAH = carcinogenic polycyclic aromatic hydrocarbons; EAA = early action area; HHRA = human health risk assessment; HQ = hazard quotient; LOAEL = lowest observed adverse effect level; PCB = polychlorinated biphenyl; RME = reasonable maximum scenario
SWAC = spatially-weighted average concentration

Table A4 Individual Risk Driver Excess Cancer Risks for Human Health RME Direct Contact Scenarios

Receptor Group	Arsenic Risks									
	Time from Beginning of Construction (years)									
	0[a]	*5*[b]	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Site-wide Netfishing	4E-06	3E-06	3E-06	3E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06
Tribal Clamming	1E-05	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
Beach 1	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 2	5E-06	4E-06	4E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 3	4E-06	4E-06	4E-06	4E-06	4E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 4	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 5	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 6	4E-06	4E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 7	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06
Beach 8	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06

Receptor Group	Total PCB Risks									
	Time from Beginning of Construction (years)									
	0[a]	*5*[b]	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Site-wide Netfishing	1E-07	5E-08	4E-08	4E-08	4E-08	3E-08	3E-08	3E-08	3E-08	3E-08
Tribal Clamming	4E-07	1E-07	1E-07	1E-07	9E-08	9E-08	9E-08	9E-08	9E-08	9E-08
Beach 1	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08
Beach 2	2E-07	5E-08	4E-08	3E-08	3E-08	3E-08	3E-08	2E-08	2E-08	2E-08
Beach 3	6E-08	4E-08	4E-08	4E-08	4E-08	4E-08	4E-08	4E-08	4E-08	4E-08
Beach 4	6E-07	3E-08	3E-08	3E-08	3E-08	3E-08	2E-08	2E-08	3E-08	2E-08
Beach 5	7E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08	3E-08
Beach 6	3E-07	4E-08	3E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08
Beach 7	3E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08
Beach 8	3E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08	2E-08

Receptor Group	cPAH Risks[c]									
	Time from Beginning of Construction (years)									
	0[a]	*5*[b]	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Site-wide Netfishing	9E-07	4E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07
Tribal Clamming	2E-06	9E-07	8E-07	7E-07	7E-07	7E-07	7E-07	7E-07	7E-07	7E-07
Beach 1	4E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
Beach 2	8E-06	2E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	9E-07
Beach 3	4E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	2E-06
Beach 4	4E-06	2E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
Beach 5	4E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
Beach 6	6E-06	2E-06	1E-06	1E-06	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07
Beach 7	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
Beach 8	2E-06	9E-07	8E-07	8E-07	8E-07	8E-07	8E-07	8E-07	8E-07	8E-07

Receptor Group	Dioxin/Furan Risks									
	Time from Beginning of Construction (years)									
	0[a]	*5*[b]	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Site-wide Netfishing	6E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07
Tribal Clamming	2E-06	4E-07	4E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07
Beach 1	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
Beach 2	8E-07	3E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
Beach 3	3E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
Beach 4	2E-06	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
Beach 5	3E-07	1E-07	1E-07	1E-07	2E-07	1E-07	2E-07	2E-07	2E-07	1E-07
Beach 6	3E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07
Beach 7	2E-07	1E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
Beach 8	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07

Notes:

1. Risk estimates are based on SWACs for netfishing, tribal clamming, and individual beaches predicted by the BCM.
2. Non-cancer hazard quotient is less than 1 for total PCBs following completion of the EAAs for all beach play areas, and for Beach 4 following completion of construction.

a Estimated conditions following completion of the EAAs. Also, year 0 is the assumed start of construction and start of the BCM.
b The construction period is estimated at 5 years.
c All hot spots in beaches are actively remediated to achieve RAO 2 at the end of construction. Some beaches are shown to have excess cancer risks that slightly exceed the 1×10^{-6} threshold at the end of construction. This is an artifact of using a post-remedy bed sediment replacement value of 140 µg TEQ/kg. Given the uncertainty in this value and the fact that the beaches are actively remediated, it is assumed that risk from cPAHs at these beaches will be 1×10^{-6} following construction.

$> 1 \times 10^{-6}$ and $\leq 1 \times 10^{-5}$	Colored cells indicate residual excess cancer risk.
$\leq 1 \times 10^{-6}$	

BCM = bed composition model; cPAH = carcinogenic polycyclic aromatic hydrocarbon; EAA = early action area; PCB = polychlorinated biphenyl; RAO = remedial action objective; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent

Table A5 Comparative Evaluation and Relative Ranking of Remedial Alternatives[a]

Evaluation Criteria			Final FS Remedial Alternative												Combined Elements
			1	2R	2R-CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R	
Overall Protection of Human Health and the Environment	Magnitude of Residual Risk	RAO 1: Residual risk from total PCBs – Adult Tribal RME[b,c]	All alternatives and the Combined Elements are predicted to achieve an excess cancer risk of 2 x 10^{-4} and non-cancer risk of HQ=4 (except Alternative 1, which is predicted to achieve an HQ of 5) in the long term. Times required to reach lowest predicted surface sediment concentrations vary (see Short-term Effectiveness section of this table). All alternatives and the Combined Elements will require seafood consumption advisories.												
		RAO 2: Residual direct contact excess cancer risk – cumulative[d]	All alternatives and the Combined Elements are predicted to achieve a cumulative excess cancer risk of < 1 x 10^{-5}.												
		RAO 3: Benthic	All alternatives (except Alternative 1) and the Combined Elements are predicted to achieve the SQS and thereby achieve RAO 3 (see Table 9-2b). Alternative 1 may require more than 10 years of natural recovery to achieve RAO 3.												
		RAO 4: HQ for consumption of seafood by the river otter	All alternatives and the Combined Elements are predicted to achieve HQ <1 following construction.												
	Adequacy & Reliability of Controls	Achievement of RAOs	Not expected to achieve all RAOs.	All alternatives and the Combined Elements rely on a combination of engineering and institutional controls to achieve protectiveness for RAO 1.											
		Types of controls used to achieve RAOs	Not expected to achieve all RAOs.	Least use of dredging/capping (29/3 acres) and most MNR. No ENR.	Same as 2R, but adds long-term management of in-waterway CAD.	More dredging/capping (29/19 acres) than Alt 2, less MNR. 10 acres ENR/*in situ*.	More dredging than capping (50/8 acres) than 3C. Same MNR as 3C. No ENR.	More dredging/capping (50/41 acres) than Alt 3, less MNR. 16 acres ENR/*in situ*.	More dredging than capping than 4C (93/14 acres). Same MNR as 4C. No ENR.	More dredging/capping (57/47 acres) and more ENR/*in situ* compared to Alt 4. No MNR.	More reliance on dredging than capping (143/14 acres) than 5C. No ENR or MNR.	Same as 5R, adds ex-situ treatment.	Most dredging/capping (108/93 acres). 101 acres ENR/*in situ*. No MNR.	Most dredging rather than capping (274/28 acres). No ENR or MNR.	Dredging/capping in the most contaminated areas 38/34 acres). *In situ* treatment of 65 acres to reduce bioavailability. MNR allowed only in areas below Human Health RALs.
		Institutional Controls	No ICs	Seafood consumption advisories are required to manage residual seafood consumption risks. Proprietary controls (e.g., restrictive covenants) are also needed to manage residual contamination left in place. The number and importance of these proprietary controls progressively diminishes as the amount of dredging and capping increases because the amount of contamination left in place is correspondingly diminished.											
		Monitoring and maintenance (area in acres remediated by (capping)/ (ENR/*in situ*)	Only EAAs monitored and maintained.	3/0	3/0	19/10	8/0	41/16	14/0	47/53	14/0	14/0	93/101	28/0	34/65
		Monitoring (area in acres remediated by MNR)		19(MNR10) 106(MNR20)	19(MNR10) 106(MNR20)	99(MNR20)	99(MNR20)	50(MNR10)	50(MNR10)	0	0	0	0	0	20(MNR10)
	Summary of Short-term Effectiveness		Low short-term impacts during construction but contamination remains above protective levels.	Low short-term impacts during construction. Long time to achieve RAOs. High natural recovery prediction uncertainty.		Low short-term impacts during construction and moderate time to achieve RAOs. Moderate natural recovery prediction uncertainty. .		Moderate short-term impacts during construction and moderate time to achieve RAOs. Low natural recovery prediction uncertainty.	High short-term impacts during construction and moderate time to achieve RAOs. Low natural recovery prediction uncertainty.	Moderate short-term impacts during construction and moderate time to achieve RAOs. Very low natural recovery prediction uncertainty.	High short-term impacts during construction and long time to achieve RAOs. Very low natural recovery prediction uncertainty.		High short-term impacts during construction and long time to achieve RAOs. Very low natural recovery prediction uncertainty.		Low short-term impacts during construction and lowest time to achieve RAOs. Low natural recovery prediction uncertainty.
	Summary of Overall Protection of Human Health and the Environment		Does not provide adequate overall protection to human health and the environment.	All alternatives and the Combined Elements achieve overall protection to human health and the environment in varying time frames and varying reliance on natural recovery. All require institutional controls to fully achieve protectiveness. Longer construction periods result in proportionately greater short-term impacts. Dredging or capping a larger surface area has a lower potential for subsurface contamination to be re-exposed by natural or mechanical disturbances (e.g., scour). The potential to re-expose of subsurface contaminated sediment diminishes as more contaminated sediment is dredged. Re-exposure of subsurface contaminated sediment is less of a concern for maintaining PRGs based on SWACs than for maintaining PRGs that are based on point concentrations (e.g., the SMS COCs).											
Comply with or Waive ARARs	Compliance with ARARs	Water Quality Standards	No active remedial measures are feasible or anticipated for the water column although significant water quality improvements are anticipated from sediment remediation and source control. It is not anticipated that any alternative or the Combined Elements can 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.												
		Sediment Management Standards	Not expected to comply.	Alternatives 2R and 2R-CAD predicted (high model uncertainty) to achieve the SQS approximately 10 years after construction		Alternatives 3C and 3R are predicted to achieve the SQS approximately 5 years after construction.		Alternatives 4 through 6 are predicted to achieve the SQS immediately following construction.							Predicted to achieve the SQS immediately following construction.
		MTCA – Human Health Seafood Consumption	Not expected to comply.	Alternatives 2 through 6 and the Combined Elements require institutional controls in addition to engineering controls to comply with MTCA because the MTCA requirement to achieve natural background for final cleanup actions is not achievable.											
		MTCA – Human Health Direct Contact	Not expected to comply.	All alternatives and the Combined Elements achieve the cumulative direct contact goal of 1 × 10^{-5}. They also achieve individual chemical risk thresholds of 1 × 10^{-6} for total PCBs and dioxins/furans. All exposure areas are between 1 × 10^{-5} and 1 × 10^{-6} cancer risk for arsenic and all are above the UCL95 of the natural background dataset for arsenic (the arsenic PRG is natural background). All exposure areas are at or below an individual cPAH risk of 1 × 10^{-6} except for Beach 3 where predictions are influenced by a lateral source.											
	Summary of ARARs		Not expected to comply.	No alternatives or the Combined Elements are expected to comply with all surface water quality standards, or with natural background sediment standards required under MTCA (for risk-based RBTCs below background). Surface water quality and MTCA ARAR waivers would be required at or before completion of the remedial action.											
Achieve Threshold Requirements			No	Alternatives and the Combined Elements require one or more ARAR waivers to meet threshold criteria.											

Table A5 Comparative Evaluation and Relative Ranking of Remedial Alternatives[a]

Evaluation Criteria			Final FS Remedial Alternative: 1	2R	2R-CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R	Combined Elements
Long-term Effectiveness and Permanence	Magnitude of Residual Risk (Contaminated sediment remaining in the subsurface)	Total dredge area outside of EAAs (acres)	n/a	29	29	29	50	50	93	57	143	143	108	274	38
		Total cap, partial dredge/cap, and *in situ* application area [e]	n/a	3	3	24	8	49	14	74	14	14	143	28	99
		Total ENR/*in situ* application area (in Category 1/Categories 2 & 3 combined; acres) [e, f]	n/a	0/0	0/0	0/10	0/0	0/16	0/0	1/52	0/0	0/0	1/100	0/0	16/49
		Total MNR application area (in Category 1/Categories 2 & 3 combined; acres) [e, f]	n/a	24/101	24/101	20/79	20/79	3/47	3/47	0/0	0/0	0/0	0/0	0/0	2/18
		Post-construction number of core stations remaining >CSL in the FS dataset (under caps/ all other locations)[g]	n/a	0/37	0/37	15/32	1/24	18/26	1/14	20/22	1/5	1/5	27/8	1/0	16/33 - (26 *in situ*, 2 MNR and 5 VM)
		Potential for Re-exposing Remaining Subsurface Contamination	Largest amount of subsurface contamination and greatest potential for re-exposure.	Moderate potential for re-exposure. Localized impacts unlikely to affect SWACs	Same as for 2R plus: majority of contaminated sediment remains on site in CAD.	Moderate potential for re-exposure. Localized impacts unlikely to affect SWACs.	Same as for 3C plus: Lower residual subsurface contamination than 3C.	Low potential for re-exposure. Localized impacts unlikely to affect SWACs	Same as for 4C plus: lower residual subsurface contamination than 4C.	Low potential for re-exposure. Localized impacts unlikely to affect SWACs.	No designated ENR and MNR areas. Very low potential for re-exposure. Lower residual subsurface contamination than 5C.	Same as for 5R.	Large ENR area but low potential for re-exposure. Localized impacts unlikely to affect SWACs.	No designated ENR and MNR areas. Least amount of residual subsurface contamination. Very low potential for re-exposure.	Low potential for re-exposure through the use of scour mitigation measures. Localized impacts unlikely to affect SWACs
	Adequacy and Reliability of Controls [h]	Relative amount of monitoring and maintenance required (based on total cap, ENR/*in situ* and MNR area – see number of acres above).	Low – only EAAs monitored	Large area (128 acres)	Large area (128 + 23 acres of CAD)	Large area (128 acres)	Large area (107 acres)	Large area (107 acres)	Moderate area (64 acres)	Large area (100 acres)	Small area (14 acres)		Large area (194 acres)[i]	Small area (28 acres)	Large area (119 acres)
	Adequacy and Reliability of Controls – Magnitude and Duration of Institutional Controls	Monitoring and notification of waterway users (based on total cap, ENR, and MNR area; acres)	No institutional controls	Same relative rankings as for monitoring and maintenance (see above).											
		Seafood consumption advisories, public outreach, and education	No outreach or education	Similar seafood consumption advisories, public outreach, and education are required for all alternatives and the Combined Elements.											
		Summary	No institutional controls	The need for monitoring and maintenance is higher for combined alternatives and the Combined Elements and less for removal alternatives with the same RALs. Similar seafood consumption advisories, public outreach, and education are required in all cases.											
	Summary		Low – only EAAs remediated. Not expected to achieve all RAOs.	Lower numbered alternatives and the Combined Elements leave a greater amount of contaminated subsurface sediment in place than the higher numbered alternatives and also have greater monitoring and maintenance requirements. Removal alternatives have fewer FS dataset cores >CSL remaining after construction than their combined technology counterparts (including the Combined Elements). Monitoring, maintenance, and ICs are considered adequate and reliable in all cases.											
	Relative ranking (★= Lowest for long-term effectiveness and permanence)		★	★★	★	★★★	★★★	★★★★	★★★★	★★★★	★★★★★	★★★★★	★★★★	★★★★★	★★★★
Reduction of Toxicity, Mobility, or Volume through Treatment	*Ex situ* treatment of dredged material		None	None	None	None	None	None	None	None	None	Treatment by soil washing to potentially reduce volume of waste requiring landfill disposal	None	None	None
	In situ treatment (Area in acres potentially treated *in situ* is assumed to be 50% of total ENR and *in situ* treatment area)		0	0	0	5	0	8	0	26.5	0	0	50.5	0	Up to 65
	Relative ranking based on amount of material managed[i] (★= Lowest for Reduction of Toxicity, Mobility or Volume)		★	★	★	★★	★	★★	★	★★★	★	★★★★	★★★	★	★★★★

Table A5 Comparative Evaluation and Relative Ranking of Remedial Alternatives[a]

		Evaluation Criteria	Final FS Remedial Alternative: 1	2R	2R-CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R	Combined Elements
Short-term Effectiveness	Protection during Construction	Period of community exposure (including noise), worker exposure, ecological disturbance and resuspension of contaminated material from dredging (years of construction)[j]	0	4	4	3	6	6	11	7	17	17	16	42	5
		Dredge-cut prism volume/Performance contingency; cy	Not estimated	370,000/ 580,000	370,000/ 580,000	300,000/ 490,000	590,000/ 760,000	560,000/ 690,000	1,000,000/ 1,200,000	640,000/ 750,000	1,600,000/ 1,600,000	1,600,000/ 1,600,000	1,500,000/ 1,600,000	3,900,000/ 3,900,000	470,000/ 620,000
		Air quality impacts (CO_2/PM_{10}; metric tons)	Not estimated – Lowest impact	24,000/ 21	18,000/ 22	22,000/ 19	32,000/ 29	32,000/ 28	49,000/ 44	35,000/ 31	70,000/ 63	61,000/ 57	75,000/ 67	164,000/ 148	29,000/ 25
		Ecological – Habitat area shallower than -10 ft MLLW disturbed (dredging and capping)	Not estimated – Lowest impact	13	13	28	28	42	42	59	59	59	99	99	27
	Time to achieve RAOs or important risk reduction milestones (years)[k]	RAO 1: 10^{-4} magnitude PCB risk (Adult Tribal RME)[l]	5	4	4	3	6	6	11	7	17	17	16	42	5
		RAO 1: Predicted time for total PCBs and dioxins/furans to reach long-term model-predicted concentration range in surface sediment[l]	25	24	24	18	21	16	21	17	22	22	16	42	15
		RAO 2: Cumulative risk $\leq 1 \times 10^{-5}$ (All exposure scenarios)[m]	0	0	0	0	0	0	0	0	0	0	0	0	0
		RAO 3: Benthic invertebrates (SQS)[n]	20	14	14	8	11	6	11	6	11	11	6	11	5
		RAO 4: Ecological – river otter (HQ<1)[o]	< 5	4	4	3	6	6	11	7	17	17	16	42	5
	Summary of short-term effectiveness		No construction (other than EAAs). Contamination remains above protective levels.	Low impacts from construction. Moderate time to reduce contaminant concentrations. High uncertainty (125 acres MNR).	Slightly more impacts from construction than 2R due to CAD. Similar time to reduce contaminant concentrations. High uncertainty (125 acres of MNR).	Similar impacts from construction, shorter time to reduce contaminant concentrations, and less uncertainty than Alt 2 (99 acres MNR).	Higher impacts from construction, longer time to reduce contaminant concentrations, and less uncertainty than 3C (99 acres MNR).	Similar impacts from construction, similar time to reduce contaminant concentrations, and lower uncertainty than 3R (50 acres MNR).	Higher impacts from construction, similar time to reduce contaminant concentrations, and similar uncertainty to 4C (50 acres MNR).	Impacts from construction similar to 3R, and higher than 4C. Shorter time to reduce contaminant concentrations. Very low uncertainty (no MNR).	More impacts from construction than 4R, but less than 5C. Longer time to reduce contaminant concentrations. Very low uncertainty (no MNR).		More impacts from construction, similar time to reduce contaminant concentrations, and lower uncertainty than 5R (no MNR).	Highest impacts from construction and longest time to reduce contaminant concentrations with lowest uncertainty (no MNR).	Impacts from construction and time to reduce contaminant concentrations lower than 4C. Low uncertainty (20 acres MNR)
	Relative Ranking (★ = Lowest for short-term effectiveness)		★	★★	★★	★★★★	★★★	★★★★	★★★	★★★★	★★	★★	★★	★	★★★★★
Implementability	Technical and administrative feasibility during construction		No construction (other than EAAs)	Short construction period. Lowest potential for difficulties and delays.	Same as 2R plus significant administrative issues with siting, maintenance, and liability of CAD.	Same construction period as Alt 2. Low potential for difficulties and delays.	Longer construction period than 2 or 3C. Low potential for difficulties and delays.	Similar construction period to 3R. Low potential for difficulties and delays.	Longer construction period than 4C. Higher potential for difficulties and delays.	Construction period slightly longer than 4C, and shorter than 4R. Potential for difficulties and delays similar to 4C.	Longer construction period than 4R. Higher potential for difficulties and delays.	Same as 5R plus significant issues with permitting facility and reusing treated material.	Construction period similar to 5R. Similar potential for difficulties and delays.	Longest construction period. Highest potential for and delays.	Shorter construction period than 4C. Low potential for difficulties and delays.
	Technical and administrative burden of evaluating monitoring data, considering and implementing contingency actions.		No contingency actions contemplated.	High potential for additional actions in MNR and ENR areas.	Same as 2R.	Lower potential for additional actions in MNR and ENR areas than Alt 2.	Same as 3C.	Lower potential for additional actions in MNR and ENR areas than 3R.	Lower potential for additional actions in MNR areas than 4C.	Additional actions may be needed after dredging to meet low RALs. Potential for additional actions in ENR areas similar to 4R.	Same as 5C.	Same as 5R.	Additional actions likely needed after dredging to meet lower RALs. No MNR or ENR.	Same as 6C.	Extensive use of *in situ* treatment and scour mitigation reduces potential for additional actions compared to 4C and 5C.
	Summary of implementability		High	Moderate	Low	Moderate	Moderate	High	High	High	Low	Very Low	Low	Very Low	High
	Relative ranking (★ = Lowest for implementability)		★★★★	★★★	★★	★★★	★★★	★★★★	★★★★	★★★★	★★	★	★★	★	★★★★
Costs	Total (MM$)		66[p]	210	200	200	270	260	360	290	470	510	530	810	260
	Relative ranking (★ = highest for cost)		★★★★★	★★★★	★★★★	★★★★	★★★	★★★	★★	★★★	★★	★★	★★	★	★★★★

Notes:

a. Relative ranking compares alternatives and the Combined Elements to one another using a one star (★= low ranking) to five star (★★★★★= high ranking) system. See specific criteria for guide to interpreting star rankings.

b. Risk estimate is based on use of the total PCB SWAC (using base case [mid input values] BCM output) in the food web model. Total excess cancer risks (all carcinogens combined) are expected to be similar to total PCB risks for the consumption of resident fish and crab (this does not include risks due to clam consumption where risks are largely due to arsenic and cPAHs in clam tissue).

c. See Table 9-7a for other RME risk scenarios.

d. Base case (mid input values) BCM output used for cumulative (i.e., contributions of all four risk-driver chemicals) risk estimation. Cumulative risks lower than 1×10^{-5} are within the acceptable CERCLA risk range.

e. The proportion of ENR or *in situ* treatment is assumed to be 50%/50% for the FS alternatives and up to 100% *in situ* for the Combined Elements. *In situ* is assumed to be implemented in conjunction with scour mitigation technologies, as needed, and to have a similar degree of protectiveness with respect to potential re-exposure of subsurface contamination as capping.

f. Recovery categories: Category 1 – presumed to be limited; Category 2 – less certain; Category 3 – predicted to recover.

g. Remaining cores grouped by those located under caps and those located anywhere else at the site after construction.

h. This analysis evaluates the reliability of controls after RAOs are achieved. The construction periods differ (see Short-term Effectiveness) and various controls will also be required during construction.

i. Alternative 6C extends project-specific O&M and monitoring into AOPC 2 (i.e. for capping, and ENR / *in situ)* and is the only alternative to do so.

j. Construction period rounded to nearest year. Additional time beyond construction required for ecologically sensitive areas to recover. Also, fish and shellfish tissue contaminant concentrations may require additional time after construction to recover.

k. The predicted time to achieve RAOs is keyed to the start of construction, except for Alternative 1 which is keyed to the completion of the EAAs.

l. No remedial alternative or the Combined Elements achieve RAO 1 PRGs without an ARAR waiver. All alternatives achieve RAO 1 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 point the alternatives reduces the Adult Tribal RME seafood consumption risk to 10^{-4}, and 2) the predicted time for total PCBs and dioxins/furans concentrations to achieve long-term model-predicted concentration ranges. 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. The food web model relationship between sediment and fish tissue concentrations is assumed to not apply during construction. Fish tissue concentrations are expected to remain elevated as a result of resuspension and release of total PCBs into the water column.

m. Alternatives 3C and 3R specifically address direct contact risks and achieve a cumulative direct contact risk of $\leq 1 \times 10^{-5}$ for all exposure scenarios. It is assumed that the Alternative 3 actions occur at the beginning of Alternatives 4, 5, and 6 (and the Combined Elements); these alternatives are assumed to have the same times to achieve the other RAO 2 metrics as described for Alternatives 3C and 3R. Alternative 2 does not actively remediate for all direct contact risks. However, surface sediments in tribal clamming and beach play areas are $\leq 1 \times 10^{-5}$ following construction of EAAs and are expected to continue recovering naturally over time. See Figure 3 for times for individual risk drivers to achieve cancer risk threshold.

n. The time to achieve 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.

o. The time to achieve RAO 4 is when wildlife seafood consumption HQ <1 is achieved based on the site-wide total PCB SWAC at the end of construction.

p. EAAs are approximately 29 acres. The areas and estimated in water remediation costs for Alternative 1 (EAAs) are provided for informational purposes only and are not included in the respective area and cost totals for the other alternatives.

AOPC = area of potential concern; BCM = bed composition model; C = combined alternative; CAD = contained aquatic disposal; CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; cPAH = carcinogenic polycyclic aromatic hydrocarbon; CSL = cleanup screening level; cy = cubic yards; EAA = early action area; ENR = enhanced natural recovery; HQ = hazard quotient; IC = institutional control; MLLW = mean lower low water; MM = million; n/a = not applicable; MNR = monitored natural recovery; PCB = polychlorinated biphenyls; R = removal alternative; RAL = remedial action level; RAO = remedial action objective; RME = reasonable maximum exposure; R-T = removal alternative with treatment; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95 percent upper confidence limit on the mean; VM = verification monitoring.

Table A6 MTCA Disproportionate Cost Analysis and Ranking

Evaluation Criteria			Weighting Factor	Benefit Scoring Basis[a]		Units	Site-wide Remedial Alternatives												
				Score 0	Score 10		1	2R	2R-CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R	Combined Elements
1	Overall Protectiveness of Human Health and the Environment		25%			Overall Score	2.5	4.0	4.0	5.2	5.0	6.2	5.2	6.9	5.0	5.0	7.2	4.0	6.8
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	1158	1038	1038	950	950	818	913	783	918	918	655	843	783
	Score 0 represents predicted exposure with natural recovery but without construction (i.e., Alt 1; 1158 (µg/kg dw)yrs); score 10 represents no action at the start of construction, followed by the asymptote (39 µg/kg dw) from 5-45 years following initiation of construction (353 (µg/kg dw)yrs).					Score	**0.0**	**1.5**	**1.5**	**2.6**	**2.6**	**4.2**	**3.0**	**4.7**	**3.0**	**3.0**	**6.2**	**3.9**	**4.7**
1b	Cumulative benthic exposure	SQS exceedances integrated over time.[c]	25%	2,055	560	exceedance yrs	2055	1465	1465	1090	1090	900	975	560	830	830	560	830	680
	Score 0 represents predicted exposure with natural recovery but without construction (i.e., Alt 1; 2055 exceedance-yrs); score 10 represents no action at the start of construction, followed by no exceedances fron 5-30 years following initiation of construction (585 exceedance-yrs).					Score	**0.0**	**3.9**	**3.9**	**6.5**	**6.5**	**7.7**	**7.2**	**10.0**	**8.2**	**8.2**	**10.0**	**8.2**	**9.2**
1c	Risks from implementation	Construction time. Assume that impacts during dredging are proportional to construction time when comparing remedial alternatives.	25%	42	0	yrs	0	4	4	3	6	6	11	7	17	17	16	42	5
	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	**10.0**	**9.0**	**9.0**	**9.3**	**8.6**	**8.6**	**7.4**	**8.3**	**6.0**	**6.0**	**6.2**	**0.0**	**8.8**
2	Permanence		20%			Overall Score	0.0	2.4	1.9	2.7	3.1	3.8	4.6	4.4	6.2	6.2	6.0	9.6	4.1
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	0.00	0.58	0.27	0.49	0.76	0.69	1.20	0.75	1.60	1.60	1.60	3.90	0.63
	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	**0.0**	**1.5**	**0.7**	**1.3**	**1.9**	**1.8**	**3.1**	**1.9**	**4.1**	**4.1**	**4.1**	**10.0**	**1.6**
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	0	29	5	29	50	50	93	57	143	143	69	164	38
		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	0	3	27	19	8	41	14	47	14	14	61	16	34
		in situ treatment		weighting: 7		acres of AOPC 1	0	0	0	5.0	0	8	0	26.5	0	0	25.0	0	65.0
		ENR		weighting: 4		acres of AOPC 1	0	0	0	5.0	0	8	0	26.5	0	0	25.0	0	0
		MNR and VM		weighting: 2		acres of AOPC 1	0	148	148	122	122	73	73	23	23	23	0	0	43
	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 are not remediated (0), or removed completely from the LDW (10).					Score	**0.0**	**3.3**	**3.2**	**4.0**	**4.3**	**5.8**	**6.2**	**7.0**	**8.2**	**8.2**	**7.9**	**9.1**	**6.6**

Table A6 MTCA Disproportionate Cost Analysis and Ranking

Evaluation Criteria			Weighting Factor	Benefit Scoring Basis[a]		Units	Site-wide Remedial Alternatives												
				Score 0	Score 10		1	2R	2R-CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R	Combined Elements
3	Effectiveness Over the Long Term		30%			Overall Score	2.5	3.6	3.4	4.1	4.6	5.5	6.4	6.0	8.3	8.3	6.9	9.2	6.0
3a	Degree of certainty that the remedy 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	0	29	5	29	50	50	93	57	143	143	69	164	38
		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	0	3	27	19	8	41	14	47	14	14	61	16	34
		in situ treatment		weighting: 7		acres of AOPC 1	0.0	0.0	0.0	5.0	0.0	8.0	0.0	26.5	0.0	0.0	25.0	0.0	65.0
		ENR		weighting: 6		acres of AOPC 1	0.0	0.0	0.0	5.0	0.0	8.0	0.0	26.5	0.0	0.0	25.0	0.0	0.0
		MNR and VM		weighting: 3		acres of AOPC 1	180	148	148	122	122	73	73	23	23	23	0	0	43
	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 are not remediated (0), or removed completely from the LDW (10).					Score	3.1	4.2	4.2	4.7	5.0	6.2	6.7	6.8	8.4	8.4	7.6	9.2	7.0
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 relieability 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	180	151	175	151	130	130	87	123	37	37	111	16	142
	Score of 0 represents capping, ENR, MNR, or VM all of AOPC 1; score of 10 represents dredging all of AOPC 1.					Score	0.0	1.6	0.3	1.6	2.8	2.8	5.2	3.2	7.9	7.9	3.8	9.1	2.1
4	Management of Short-term Risks		15%			Overall Score	10.0	8.8	8.3	8.9	8.3	8.1	7.1	7.9	5.8	5.0	5.4	0.0	8.3
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	0.71	1.2	0.76	1.0	1.2	1.6	1.3	2.2	3.0	2.8	5.1	1.10
	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	10.0	8.6	7.6	8.5	8.0	7.6	6.9	7.5	5.7	4.1	4.5	0.0	7.8
4b	Effectiveness of protective measures to manage short-term risks	Assume that impacts during dredging are proportional to construction time.	50%	42	0	years	0.0	4.0	4.0	3.0	6.0	6.0	11.0	7.0	17.0	17.0	16.0	42.0	5.0
	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	10.0	9.0	9.0	9.3	8.6	8.6	7.4	8.3	6.0	6.0	6.2	0.0	8.8
5	Technical and Administrative Implementability		5%			Overall Score	4.0	6.0	4.0	6.0	6.0	8.0	8.0	8.0	4.0	2.0	4.0	2.0	8.0
	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	0.0	1.0	0.0	5.0	3.0	5.0	5.0	7.0	7.0	7.0	7.0	8.0	7.0
	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	3.1	4.2	3.9	5.0	5.0	5.8	5.9	6.4	6.4	6.2	6.4	6.2	6.3
8	Cost					$millions net present value - excluding EAAs	0	210	200	200	270	260	360	290	470	510	530	810	260
9	Benefit/cost					Benefit/$billion	NA	20.0	19.5	25.0	18.5	22.3	16.4	22.1	13.6	12.2	12.1	7.7	24.2

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. Calculation: (Average PCB concentration over 45 years - 39 µg/kg dw) x 45 years

c. Exceedance estimate based on the best estimate (mid input values) BCM output for representative SMS chemicals. Calculation: (Average number of point exceedances over 30 years) x 30 years

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 nodel; 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.